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JOURNAL

OF THE

AMERICAN WELDING SOCIETY

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33 West Thirty-ninth Street, New York

American Welding Society

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JOURNAL
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AMERICAN WELDING SOCIETY

ESTABLISHED 1919

JOURNAL

VOL. 2. APRIL, 1923. NO. 4

PRESIDENT C. A. McCUNE

Those of us who have been in close touch with the affairs of the Society during the past year, find it difficult to express in words our appreciation of the splendid work done by our retiring President, C. A. McCune. Much more would it be difficult to express our deep affection for him as a friend.

Since its organization the Society has

CHARLES A. McCUNE

been struggling to maintain high scientific standards in its output as well as high ideals of real service to the industries, in the face of extraordinary obstacles which, due to to the good work already done have now largely disappeared. There have been many times when the fight looked hopeless to all except the few who had the courage and conviction of an ideal. From the beginning President McCune has been one of the most active of this little group, always confident of success, always cheerful, everlastingly on the job, and in general a tonic and an inspiration to his fellow-workers.

Prior to his term as President he was Chairman of the Membership Committee, and through his untiring efforts, his wide acquaintance and high standing, contributed largely to the upbuilding of the Society.

When he became President the Society was in a very critical financial condition. The publication of our own Journal had just been undertaken, with the conviction that it was the right thing to do; but with the full realization that it could only succeed as a result of an enormous amount of hard work on the part of all cerned; and it has succeeded in spite of the gloomy forebodings of the pessimists.

Here again President McCune was a large factor in "putting it over," and has guided our ship safely through its financial rough seas into comparatively smooth water. For the first time in its history the Society is on a sound financial basis and can show a balanced budget.

Very few of the readers of this Journal can realize the vision, the courage and the hard work, that has been necessary to place our Society on a sound foundation. Neither can they realize fully its service to the industry and what it stands for. Its accomplishments are not all matters of public record.

Here's to you Charlie McCune; more strength to your right arm; may long life, health and happiness be yours, and may you never stop working for the American Welding Society.

ANNUAL MEETING OF THE AMERICAN WELDING SOCIETY

The attention of our members is again called to the special features of the annual meeting of the Society. The business session on Wednesday morning, April 25th will include a review of the progress made during the past year by the Society. The special feature of this

occasion is the presentation of four reports giving the recent developments in the electric arc, gas, thermit and resistance welding fields.

Two inspection trips have been arranged, one of them on Wednesday afternoon to the shops of the Third Avenue Railway System and the other on Friday afternoon at the plant of the Oxweld Company in Newark, N. J. The first trip provides our members an opportunity to see the applications of welding in a modern street railway shop. Members are requested to assemble in front of the Third Avenue Railway System Shops, 65th Street and Third Avenue at 1:30 p. m. sharp. In order to save time on the second inspection trip the Oxweld Company has made arrangements to transport members to Newark and thence in a special bus to their factory and to provide a luncheon for the inspection party upon arrival. Members are requested to assemble in front of the Engineering Societies Building, Friday afternoon promptly at 12.15. (Those who arrive at 12:20 will have to walk and go hungry). It is needless to point out that the courtesy of the Oxweld Acetylene Company is highly appreciated by the officers of the Society and that all members who can possibly do so should show their appreciation by going along on the trip. Primarily, this occasion provides an opportunity to see the making of a modern pressure generator from the foundry and machine department to the testing of the finished product.

The second annual dinner of the Society will be held at the Park Avenue Hotel, Wednesday evening at 7 p. m. A real worth while dinner and get-together meeting has been arranged. A good time is promised to everyone—plenty to eat and good talent. You are cordially invited to attend and bring along you friends. If you have not already made your reservations, kindly get in touch with the Secretary. Tickets are $5.00 per person.

The technical session which will be held Thursday evening is one of the most important features on the program. The results of the tests made by the Pressure Vessel Committee at the Bureau of Standards will be presented by Professor H. L. Whittemore, Chairman of the Committee. This report is one of the greatest achievements of the Society to date. For the past year or so the research department of the Society, the American Bureau of Welding has had under way the preparation of a course on the Training of Welding Operators. Mr. J. C. Wright, Director of the Federal Board of Vocational Education, who is Chairman of the Committee will present a review of what the course will include. Those who are expert claim that this course will be the best ever prepared and predict its adoption as standard by all the training schools throughout the world.

Every member of the Society who can do so should plan to attend these sessions.

ANNUAL REPORT OF MEETINGS AND PAPERS COMMITTEE

A. G. OEHLER, *Chairman.*

Meetings.

The annual fall meeting of the Society was held early in October. The particular feature of this meeting was the joint session with the A. E. R. E. A. This session marks a new era in the development of co-operation in solving the welding problems of today. The Meetings and Papers Committee recommends very strongly that additional joint sessions be arranged wherever possible with other societies and organizations. In view of the fact that the Society includes a large number of members interested in railway work it is suggested that an effort be made to arrange a joint meeting with the American Railway Association or the Boilermakers' Association at an early date. Some of the local sections have already on a number of occasions arranged to their mutual advantage joint sessions with the local sections of other engineering societies.

Although meetings of the various Sections are supposed to be held regularly every month some of them have found it difficult to secure proper speakers and attendance. The Meetings and Papers Committee has under consideration, means for closer co-operation with the Sections with the idea of providing such assistance as it can render.

Publications

Beginning with January 1922, the Society has been publishing regularly its

own monthly Journal. In addition to technical papers, the Journal includes news items and reports of the Society, local sections, the American Bureau of Welding and the industry. There are also included suitable editorials, employment service bulletin, bibliography, current welding literature and from time to time names of new members.

In the 1922 volume there was published 413 pages of technical papers and reports and 90 pages of news items, editorials and other material dealing with Society activities. The technical papers and reports represent some of the best contributions to welding literature made available through the technical press during the year. They include papers on safety, new applications of welding, proper technique and methods to be employed in specific cases, results of research work, new developments in apparatus and material, standardization rules, etc. An idea of their importance can be gained from a few of the titles selected at random.

Spot Welding High Carbon Steel.

Applications of Electric Arc Welding to two Vessels.

Boiler Welding.

Automatic Seam Welding

Welding High Pressure Steam Line.

Large Diameter Electrically Welded Pipes. (Results of tests included).

Oxy-Acetylene Welding of Copper Plate.

Arc Welding Monel Metal.

Commercially Pure Iron Welding Wire.

Standardization Rules of Arc Welding Apparatus (including many items of interest to prospective purchasers).

Review of Electro-Percussive Welding.

A Complete Symposim on Cast Iron Welding including a Review of the Best Available Knowledge in the Welding of Cast Iron by the Electric Arc, Thermit, and Gas Welding Processes. (Results of many tests included).

Resistance Butt Welding.

Tests to Determine Suitability of Steel for Welding Purposes.

Welded Storage Tanks.

Standards for Resistance Welding Transformers.

Locomotive Fire Box Welding.

Welding of Pipe Lines.

There can be no doubt but what the Society through the medium of the Journal is better known and appreciated. It forms a means of definite communication between the organization and its members.

Financial Aspects of the Journal.

It is interesting to note while the total expense of the Journal for the Society for 1922 was $350 that this deficit is only one-eighth of the expense of publications of previous years. For the year 1923 it is estimated that the Journal will net the Society a revenue of approximately $300 per month. These facts are brought out clearly by the figures given below:

Cost of publication for year 1921		$2,920
Cost of publication for year 1922	$5,293	
Receipts from advertising and subscriptions	4,843	
Deficit		$ 350

Budget for Year 1923

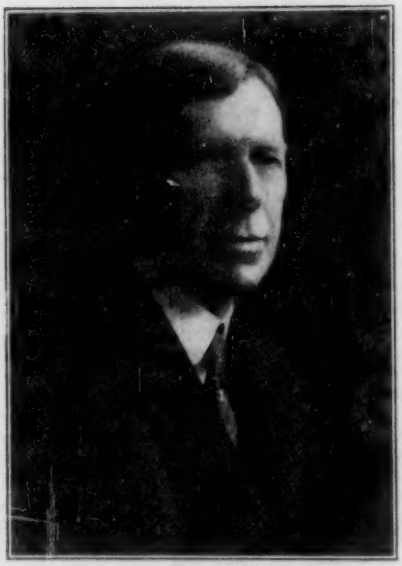
Advertising already secured	$7,956	
Journal subscriptions	600	
Estimated additional advertising	1,000	
Total	$9,556	
Estimated expense including editorial services, printing and mailing	$5,400	
Net Profit		$4,156

EMPLOYMENT SERVICE BULLETIN

Positions Vacant

V-9, Salesman. Opening for a first-class salesman to sell electric welding apparatus.

CHAIRMAN, SECTIONS



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AMERICAN WELDING SOCIETY

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Edward Thielen, Arc Welder, Illinois Steel Co., 89 and Strand Streets D

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Lubin Doncette, Electric Welder, 61 Union St., Portland Me. ..... D
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H. L. Whittemore, Engr. Bureau of Standards, Washington, D. C. D
J. C. Wright, Director, Federal Board for Vocational Education, Washington, D. C. ..... D
Leo Yates, Welder, Machine Shop, Northern Pacific R. R. Shops, So. Tacoma, Washington ..... D

RECENT DEVELOPMENTS IN THE ARC WELDING FIELD*

W. L. WARNER†

At the present time welding in some form or other is quite extensively used in repair work, and in some cases is used exclusively for manufacturing purposes. Rapid progress has been made in the art of welding during the last twenty years and we who keep in close touch with everyday welding applications do not realize the importance of the advancements that are being made from time to time.

The American Bureau of Welding which is the welding research department of the American Welding Society and National Research Council organized some ten research committees to investigate important problems and to standardize welding practice. These committees have been functioning in an energetic manner and some of them have already completed reports of their activities.

STANDARDIZATION ACTIVITIES OF THE AMERICAN BUREAU OF WELDING

Standard Tests for Welds

In May 1921, the committee on "Standard Tests for Welds" of which Mr. F. M. Farmer is chairman submitted a report. This report, which was printed as a bulletin and released in June 1921, contains a complete outline of tests necessary for shop, commercial, and research standards together with a standard procedure for mechanical testing, including tensile, bending and fatigue tests on the base metal, weld metal, and weld. The standard sizes and dimensions of test specimens are illustrated by diagrams and a short description of standard fatigue testing machines is given. This set of standards mark the starting point of standardization in the welding field.

It is more significant when one realizes that the chief difference between testing a specimen of steel that includes a welded joint and testing an ordinary specimen is the non-homogeneity of the welded specimen. The welded specimen has at its center, a section composed of material that usually has physical, chemical, and metallurgical characteristics distinctly different from the adjoining metal. Furthermore the section of the added metal is more or less irregular in shape and variable in size. Consequently the procedure prescribed for testing ordinary specimens is not applicable to specimens containing welded joints. Differences in details of procedure have caused such widely divergent results that

*Report to be presented at the Annual Meeting of the American Welding Society, April 25, 1923.
†Assistant to Chairman of the Electric Arc Welding Committee of the American Bureau of Welding.

the value of much of the research work on record up to this time has been greatly restricted. In many cases the results are actually misleading.

Welding Wire Specifications

The next report submitted was from the committee under the chairmanship of Mr. C. A. McCune on "Welding Wire Specifications." This report was published in December 1921. It included specifications for iron and steel bare electrodes and iron and steel gas welding rods, also recommended standards for coated or covered electrodes and gas welding rods for welding high carbon steel and non-ferrous metals. Chemical analyses, physical properties, sizes, marking, and materials are specified or recommended in detail. This report is the result of over a year's work by the committee and embodies all of the data available at that time.

The importance of this work is emphasized by Prof. C. A. Adams who said, "Several years ago the notion prevailed that almost any fence wire was good enough for welding and although good results were sometimes obtained from the use of fence wire, it is now recognized that most careful attention must be given to the physical as well as to the chemical characteristics of welding wire, if good results are to be assured."

Standards for Arc Welding Apparatus

In June 1922, six months later, there appeared in the Journal of the American Welding Society, a report "Standardization Rules for Electric Arc Welding Apparatus" submitted by a sub-committee of the Arc Welding Committee with Mr. William Spraragen as the chairman. From the preface to this report we learn that several types of arc welding apparatus are now being sold, but at the present time there is no agreement among the manufacturers of arc welding apparatus as to the basis of rating. A prospective purchaser is bewildered by the confusing claims that special merits pertain to the different machines on the market and, unless he has had previous experience in welding, he has no sound basis for comparing the capacities of the several makes.

This report of the sub-committee of the Arc Welding Committee contains a list of standard definitions, a classification of apparatus, and an outline of the information required to be furnished by both the supplier and the purchaser of arc welding apparatus. The committee recognizing the Standards Committee of the A. I. E. E. as the authoritative body controlling the standardization of electrical apparatus submitted these standards for their consideration. The A. I. E. E. Standards Committee appointed a sub-committee of which Mr. F. M. Farmer is chairman which has revised and enlarged the draft submitted and is now prepared to submit tentative standards.

It must be remembered however that the Standards which have been thus far completed are simply the beginning of a broader and better standardization which is being carried on as the weld-

ing art progresses. Each member of the Welding Society should feel it his duty to give constructive criticism on any point which may be incorrect or lacking in the present drafts.

GENERAL REPORTS AND RESEARCH WORK OF THE AMERICAN BUREAU OF WELDING.

Further reports by several of the committees have been in the nature of critical summaries of those phases of welding which have been studied by these committees. These critical summaries serve the two-fold purpose of giving the industry a concise statement of the best existing information and enabling a careful program of needed research to be drawn up. The importance of these reports cannot be over-estimated. In some cases a certain amount of research work has been done and is still going on. The results of these investigations are printed in the Journal of the American Welding Society from time to time and are thus made available to members of the Society and all interested persons.

Arc Welding of Cast Iron

In the August-September issue of the Journal there appears a joint report "Cast Iron Welding" by the Electric Arc, Gas, and Thermit Welding Committees of the Bureau. There is an introductory section containing a discussion of the metallurgical properties of cast iron and the factors which affect cast iron welds in general. Photomicrographs ilustrating different physical conditions in cast iron are included in this introductory section.

The section "Arc Welding of Cast Iron" was prepared by a subcommittee of the Electric Arc Welding Committee under the chairmanship of Mr. William H. Namack. This report presents a summary of the art of arc welding cast iron as it exists today, outlining the difficulties which have been encountered, and the degree of success which has been achieved. The report is divided into two parts.

In the first part, existing methods of carbon arc welding of cast iron are discussed briefly. Three methods of welding cast iron with the use of studs and the metallic arc are described and illustrated. The physical properties of cast iron which affect arc welds are discussed and corrective measures are suggested. Considerable space is given to comments by men experienced in the art of cast iron welding without the use of steel studs and it is interesting to note that there is quite a divergency of opinion among welders as to whether cast iron can be successfully welded with or without steel studs. A bibliography is included for the convenience of those who are interested in a further study of the subject.

The second part of the report "Arc Welding of Cast Iron" dealing with the research work done by Mr. Namack's committee appears in the November 1922 issue of the Journal. The committee has drawn up a proposed program of research and the report consists mainly of a description of the work which the committee has done in carying out this program. Specifications were drawn up and a series of tensile tests made on some seven different electro-

des. Diagrams and charts give the results of these tests in a graphic form and these results are also tabulated.

It is interesting to note that some of the tests show a joint efficiency ranging as high as 78% on one grade of cast iron tested and 85% on the other, there being two grades of cast iron used. These results demonstrate that it is possible to weld some grades of cast iron if the proper method and conditions of welding are obtained.

The work of Mr. Namack's Committee was carried out under the auspices of the Northern New York Section of the American Welding Society as a test of the possibilities of regional research. The facilities offered for this work were very favorable. The specimens were made through the courtesy of the General Electric Company and New York Central Railroad and were tested at Union College under the supervision of Professor McKibben. As stated by Mr. Spraragen "This reginal concentration of members permitted the holding of regular meetings at frequent intervals, of sustaining interest and enabled progress to be made at a much greater speed than could otherwise have been possible."

Specifications for Steel to be Welded

In the Welding industry, the need has long been felt for a more complete and accurate knowledge of the effects of the many variables which influence the success of a weld. A valuable contribution to our fund of information on this subject is found in a progress report of the committee on Specifications for Steel to be Welded which appears in the October 1922 issue of the Journal. The authors of the report, Mr. J. H. Nead, and Mr. R. L. Kenyon have developed a method which they propose for testing the suitability of various materials for welding purposes.

Before such a test could be developed, however, it was necessary to determine what constitutes a satisfactory material to be welded. It is generally agreed that a sound weld can only be obtained when the metal fuses evenly and quietly and without excessive sputtering and boiling. This means a material thoroughly degasified and low in gas forming elements. Freedom from slag or slag-forming constituents is also essential. With these things in mind three methods were tried.

The first method consisted in coating with vitreous enamel some sixteen-guage strips one and one half inch wide of various metals. This enamel was baked on by passing an electric current through the strips, heating them uniformly to the proper temperature. The materials tested consisted of (1) commercially pure iron made in a basic open hearth furnace, (2) copper bearing open hearth iron, (3) basic open hearth mild steel, (4) charcoal iron, (5 Bessemer steel and (6) silicon steel. The iron samples produced a perfectly smooth enamel surface free from defects, while the steel samples showed bubbles and blisters in the enamel. This indicates

that such iron has a freedom from gas and gas forming constituents.

Another set of one and one half inch sixteen guage strips was prepared but no enamel was applied. The strips were heated by an electric current as before and the current was gradually increased until the strip finally fused in two. The behavior of the samples near the fusion temperature was found to be characteristic of the materials. The iron samples melted quietly while the steel samples threw out a shower of sparks and left a very rough surface after fusion.

An oxyacetylene fusion test was applied to some sixteen gauge sheets of the same materials as just described. A four inch square of material was blocked up on a metal surface so that there was a small space between. The surface of the test piece was melted with a welding torch, moving along just fast enough to melt the metal. Good material should not "spit" or throw sparks and should show a smooth weld surface. With poor material, the spitting may be so bad as to interrupt the flow of gases and cause a backfire. The torch was also held vertically over the piece and left there until a hole was blown through. This occurs quickly with poor steel but more slowly with good material. If the rounded surface at the edge of the hole is smooth and clean, the material is good, while a rough, black spongy appearance indicates poor steel.

Of the tests that have been described it is thought that the electric fusion test on heavy plate gives the best indication of the suitability of material to be welded. The test is easily made whereever there is a butt-welder available and can be applied to samples cut from the work itself if desired. Half-inch plates seems to give the best results with a current of 8,000 amperes on a 1 ½" strip.

The photographs included in the report give striking evidence of the difference in behavior under fusion between various kinds of steel and iron. Those having a low carbon content such as commercially pure open hearth iron displayed a remarkably smooth surface under the fusion tests. Such iron fused sharply without gas evolution and sparking and flowed freely when molten. On the other hand mild steel when tested showed a quite different result. The steel effervesced during heating and boiled and bubbled near the fusion point. However mild steel with a carbon content of 0.15 is one of the most readily welded materials. In fact, specimens have been produced in ordinary ship plate which broke outside the weld. As Prof. C. A. Adams says "Although it is natural to assume that, other things being equal, the material that flows smoothly and quietly in such fusion tests is easier to weld, it is fairly obvious from experience that this is not absolutely essential to a weldable material. The real need is for specifications which when satisfied will assure the success of the weld. Such specifications will of course include the necessary tests by which the specifications may

be most readily checked. This preliminary report is a step in the right direction.

Unfired Pressure Vessels

For some time the A. S. M. E. Boiler Code Committee has been preparing a code for unfired pressure vessels similar to the boiler code. This code has been published for public hearing twice end as a proposed code once.

In a paper read before the International Acetylene Association in Chicago, October, 1922, Mr. S. W. Miller of the Committee on Welding of Pressure Vessels sets forth very clearly some of the facts in regard to the proposed code of the A. S. M. E. It is a striking example of how an industry must get together to solve a common problem.

To show that pressure vessels can be welded safely and to secure data for the Code Committee on this subject by actual tests, a committee was appointed at the April 1922 Meeting of the American Welding Society, to study the problem, Several hundred letters were sent to manufacturers and others and several replies were received. Several concerns agreed to furnish tanks and to contribute funds to test them to destruction. These tests should settle the questions at issue, the most important of which is the following, "What test will always detect an unsafe vessel?"

Mr. C. A. McCune at a recent meeting in Schenectady of the Northern New York Section of the American Welding Society stated that the Committee had secured funds and materials to the amount of $15,000 for an extensive program of research which has been completed.

Welding Oil Storage Tanks

The research activities of the American Bureau of Welding have not been confined to the problems of welding technique alone but have gradually broadened as the applications of welding have increased. By the end of 1922 we find the Welding Society interested in the welding of oil storage tanks for the oil industry to the extent that a set of preliminary specifications for the welding of a 5,000 bbl. tank have been prepared. These specifications are printed in the December 1922 issue of the Journal as a report of the Committee on Welding of Storage Tanks under the chairmanship of Mr. J. C. Lincoln.

There are many advantages of a welded tank over a riveted one. One of the most important of these is the elimination of leakage which in a riveted tank represents a loss of about 5%. This loss in a 5,000 bbl. tank represents $1,250 which captalized at 6% amounts to $20,000. It is also probable that with a little practice, the cost of erecting a tank by the electric welding method will be lower than the cost of similar tank erected by riveting.

The report contains recommendations for constructing a 5,000 bbl. tank and a number of alternate constructions are suggested.

Figures of the details of construction of the bottom, sides, and roof are given.

Welded Rail Joints

Welding is being very widely used in making street railway joints. More or less trouble has been experienced in all types of welded rail joints through breakage. Little or no scientific data exist as to the correct procedure to be followed in making welds at rail joints by the various processes. Replies received to a questionnaire sent out by the committee on Welded Rail Joints show a wide difference of procedure. These replies were published as a critical summary.

This critical summary of welded rail joints by the Welded Rail Joint Committee, under the chairmanship of Prof. G. K. Burgess of the Bureau of Standards, was published in pamphlet form in May 1922 and is a condensed statement of the present practice with the following types of welded joints:

Cast Iron Welds.
Electric resistance welds.
Electric seam welds.
Thermit welds.

Electric Seam Welds only will be considered since this paper relates exclusively to arc welding. Both carbon arc and metallic arc processes are considered below.

The A. E. R. E. A. Standard girder rails are being welded generally but the prevailing opinion seems to be that a Tee section is more readily welded than a girder section. Practical data is given for joint plates, filler rods, electrodes, fluxes, apparatus, protective accessories, methods of preparation of welds, preheating and necessary tests. In general the opinion is that the joint plates should be of low carbon steel possessing a fair ductility and that the filling material should be of the same general nature. While both the metallic and carbon arc processes are used the carbon process predominates. Some form of carbonate of soda is used as a flux in many cases. The resistance type of equipment is quite widely used as is also the generator type of welder. Head helmets and gauntlet leather gloves are used, with no leather aprons. Folding wooden screens with appropriate danger signs are used to protect passers-by. Preheating of joints is done in most cases by means of some form of torch but in many cases no preheating is done at all. The joints are generally cleaned with a wire brush. Several types of tests are suggested to determine the dependability of the joint. Among these are an actual service test to determine the strength of the joint and a rigid inspection test to determine the quality of workmanship. From all of this valuable material the Committee endeavored to layout a program of research.

In order to have a uniform type of rail and section, it was agreed that all test joints should be made on A. E. R. E. A. Standard 7 inch girder rail, Class B. Three test specimens were to be taken in each

case. In the case of patented joints, manufacturers were requested to furnish three joints for each test in addition to the test joints to be furnished by the users. The following tests were to be made on full size specimens, welded as nearly as practicable under service conditions: (a) tensile (b) drop (c) cross bending and (d) repeated impact tests. All tests were to be made to destruction.

The Committee decided that it would be desirable to have constructed a rotary service test machine of some 80 feet in diameter to simulate the wear of actual service. It was estimated that with such a machine the Committee woud be enabled to make tests in one month equivalent to five years of actual service. It was also estimated that it would cost some $14,000 to build and operate this machine for the first year. Mr. C. A. McCune made the statement before a recent meeting of the Northern New York Section of the Society that the Committee has now secured $24,000 in cash for an extensive program of research which involves more than $80,000 if materials and services are counted.

In an article appearing in the November 1922, AERA, the rotary testing machine is described. Briefly the machine consists of eight two-wheel trucks mounted tandem fashion, operating on a circular single rail track having a radius of 40 feet. The trucks are mounted on light structural frames, eight in number, said frames constructed as radial arms, the trucks being on the outer ends of the arms and the inner ends converging to a common center. Two of the trucks located opposite each other are propelled by motors designed to stand continuous operation.

The wheels are ordinary car wheels, either cast iron or steel, and the journal boxes and bearings are as nearly as possible to conform with standard designs. The track will be formed of the rails and joints, which it is desired to test. The rail will be spiked to cross ties laid on stone ballast supported on a concrete slab. The ground immediately inside the track is to be excavated to a depth of not less than 6½ feet so as to permit an observer to stand inside and make observations while the machine is in motion.

The primary purpose of this machine is to test various types of rail joints, but it will also be valuable in testing rails, wheels, axles, bearings, motors, etc. This machine will be operated at a peripheral speed of 25 miles per hour and it is assumed that it will operate for 22 hours per day, six days per week. It will be possible in a period of five weeks to obtain results equivalent to 3 to 10 years of service, depending on whether the service be heavy, medium or light.

This rotary testing machine is to be located on the grounds of the Bureau of Standards and it is expected that such close association of the work with the technical staff of the Bureau will prove of great advantage.

WELDING APPLICATIONS

In addition to the work that has been done under the auspices of the American Bureau of Welding, many investigations have been carried on by independent investigators. Some interesting applications of the welding process have been discovered and have been brought to a certain degree of development, although many phases are still in the experimental stage.

Hammer forging has been shown to greatly improve the strength, ductility and fatigue resistance of metal deposited by the electric arc. A few years ago welding currents of the order of 125 amperes were in most common use. This has gradually been increased until 200 amperes is now not unusual. For large thermal capacities 300 amperes is sometimes used with coated electrodes. This type of electrode has been very much improved and appears likely to lead to the arc welding of non-ferrous metals. Indeed, the arc welding of brass with a flux-covered type of copper electrode is already commercial in England.

Railroads

During the last few years an unusually rapid advance has been made in both electric arc and oxy-acetylene welding and they have now become recognized as arts very essential to many industries—particularly the railroad industry. Messrs. H. J. McCracken and F. J. Hickey of the Southern Pacific Railroad in the January 1923 Journal described the uses to which arc welding is put in the Sacramento Shops.

There are many instances where either oxy-acetylene or electric arc welding can be used, such as the welding of boiler tubes, repairing fire boxes, flue sheets, locomotive frames, making of car end sills and many others. The sleeves of flexible stay-bolts are welded to the wrapper sheet by the electric arc. A particularly advantageous feature of the electric arc weld is afforded through the concentration of the intense heat in a small area, enabling it to be applied just where it is needed without heating up much of the adjacent material.

The most successful applications of welding undoubtedly have been in places where thorough supervision and training of welders have been carried on, No matter what kind of material is to be welded, or what the type of welding is, the reliability of the weld rests in a large degree with the operator.

Locomotive Shops

In the field of locomotive construction and repair great progress has been made. Mr. Edward H. Heidel, boiler foreman, C. M. & St. P. R. R. in the March 1922 Journal describes the application of arc welding to locomotive boiler construction for welding fire boxes, door sheets and collars, and crown sheets. Great stress is laid on the point that only experienced welders should be allowed to make welds in fire boxes or for any pressure work. Mr. C. W. Roberts, Welding Foreman, Pennsylvania Railroad, Columbus, Ohio, in the

July 1922 Journal, describes some of the uses and abuses of arc welding in locomotive work as follows:

"In electric arc welding, as in everything else, there are limitations, and an efficient supervisor will know these limitations. He will refuse to go beyond them, as he knows such work only leads to the condemning of the entire practice of electric arc welding.

The most frequent causes of failure are inefficient and indifferent workmen and the little heed taken to have a perfectly clean properly prepared job. Suitable equipment and proper electrodes for the work at hand should not be overlooked. The finished result probably is 90 per cent operator, and 10 per cent equipment and materials, while preparation and operation are about a 50-50 break."

Mr. Roberts described several examples of welds made on various parts of locomotives, such as cross heads, side sheets, door collars and flues. Electric welding gives a stronger seam than riveting and there is never any future work necessary, such as caulking. The cost of riveting firebox seams runs from $0.90 to $1.25 per lineal foot while with the metallic electrode the total cost is approximately $0.35 per lineal foot. It is not possible to secure these good results unless the operator is a man of experience and knows what he is doing. Under these conditions arc welding gives excellent results. Mr. Roberts has secured arc welds with an efficiency as high as 96%.

Street Railways

In the maintenance of street railways electric arc welding is playing a very important part as described in the August-September 1922 Issue of the Journal by J. S. McWhirter of the Third Avenue Railway System, New York City.

The Third Avenue Railway operates approximately 1600 cars in the City of New York and in several of the adjoining municipalities. The central repair shop is located at 65th Street and 3rd Avenue, in the Borough of Manhattan.

The first use of electric welding in 1915 was the carbon arc process with graphite electrodes, the current being obtained from the 500-volt railway curcuit by stepping down the voltage through second hand car resistances. The present equipment consists of seven motor generator sets of which five are constant energy and two constant potential. There are still in use two banks of resistance fed by the railway circuit but these will be replaced as soon as operating economy justifies the change. About 25,000 lbs. of bare soft steel welding material are used per year. The average amount of welding metal used per operator is as follows: with the metallic electrode, 1.2 lbs. per man per hour, and with the graphite electrode, 1.6 lbs. per man per hour.

The welding and reinforcing of cast steel and forged truck frames and of cast-steel motor frames has been practical since 1908. The graphite electrode was used at first but now a $\frac{3}{8}$ in. metallic electrode is used with very satisfactory results.

The Welding of gear cases saves annually about $12,000 and as the majority of them are malleable iron a good grade of coated metallic electrode is used. These welds are not depended on for strength.

A large number of brake shoe heads, brake beams, side and center bearings, journal boxes, step hangars, and other truck and car body parts are reclaimed at an annual saving of about $45,000.

While it is possible and often necessary to weld malleable iron, the welds do not posses sufficient strength to justify this application on a large scale. To secure the maximum benefit from the reclaiming of truck and car body parts it is necessary that all parts which are to be welded be made of cast steel or forgings, in place of the malleable iron which is so common in electric railway car equipment.

Quoting Mr. McWhirter, "It must be said that electric welding proved a life saver to us during the war periods of inflated prices and slow deliveries.. We undoubtedly did a large amount of welding in those periods which would not be justified today, but it is a tremendous benefit to the electric railway industry to have available welding facilities which will take care of such emergencies."

Steel Mills

In the annual report of the Iron and Steel Industry Committee of the A. I. E. E. for the years 1922 considerable mention is made of the use for arc welding in steel mills.

While in general, there have been no radical changes in arc welding processes employed in steel mills within the past year, there are indications that welding will be advantageously used in an increasing number of applications in this great industry.

It is well known that the repair of worn wobblers, one of the oldest applications of electric welding in steel mills, was formerly accomplished by the carbon arc process used primarily because metal could thereby be rapidly deposited. This process is gradually being replaced by the metallic arc, with which ¼, ⅜ and½ inch diameter electrodes are used, the current values varying from 300 to 800 amperes. The use of large electrodes and heavy current values is similar to the carbon arc process in that rapid deposition of metal is accomplished, but the use of the metallic arc has the advantage over the carbon process in that a less skillful operator is required to produce reliable welds.

A departure from the more or less standardized practice of using ordinary iron electrodes for building up of worn wobblers and spindles, is that of the use of high carbon steel, recently undertaken with success by different steel companies. There have been instances where old files have actually been used as the steel for the repair of worn wobblers, and when the supply of files was exhausted, electrodes were obtained having practically the same chemical composition. In all cases, the metallic arc was used in the process of repairing.

Aside from the more or less standard welding applications such as the repair of driving spindles, pinions, chipped and worn rolls, etc., the electric arc can be used extensively in the repair of all kinds of machinery in service in a steel mill. Until actually tried, the saving effected by repairing worn or broken machinery by the electric arc, cannot be fully appreciated.

Storage Tanks

An interesting example of welding is briefly described in the October 1922 Journal by Mr. E. J. Rigby. A three million cubic feet gas holder was erected in Melbourne, Austrailia, by the Metropolitan Gas Company using the Quasi-Arc process of welding through out. The tank is 200 feet in diameter and equipped with three telescopic lifts 30 ft. high. There are over 20 miles of lap welding in the sheets and the envelope weighs 600 tons. In the whole envelope only five or six pin-holes were found. A conception of the size of this holder may be obtained by considering that as there is 30 feet of water in the bottom of it, it would accommodate a U. S. Battle Target, the welded ship Fullagar, the cross channel barge, and a few more with all their gear and with their flags flying.

Pipe Lines

Another interesting application of arc welding which has recently been employed is that of welding the joints of a pipe line. In the April 1922 Journal Mr. J. H. Nead and Mr. R. L. Kenyon describe the construction of several low pressure pipe lines for dredging and distributing systems. A particular case of this kind is that of large diameter pipe for low pressure work.

This pipe is made up by rolling flat plates of $\frac{1}{4}$" thickness into cylinders of the desired diameter and 5 ft. or more in length. When the pipe is used for steam it was found advisable to bevel the edges. After welding the longitudinal seam several cylinders are welded end to end in the trench to form a continuous pipe.

The advantages obtained by using such pipe for dredge work are several. In the first place the pipe is lighter in weight than ordinary wrought iron pipe. This is a saving both in original cost, freight, and in cost of handling and installation. Where it is necessary to carry the pipe on supports, a lighter framework can be used.

Another application of welded pipe is in the distributing system of central heating plants using low pressure steam. The pressure in such systems is generally under 25 lb. per sq. in. so that standard pipe of the required size is much heavier than is necessary to withstand the working pressure. An economy is, therefore, effected by using welded pipe, which is lighter in weight, easier to handle, and lower in cost. In one installation of 22" pipe for a district heating plant it was found that expansion joints were necessary every 125-150 ft. due to the differential expansion of the top and bottom of the pipe.

In the course of making this pipe it was found that certain pre-

cautions had to be observed in order to obtain satisfactory results. The main trouble encountered was in persuading welders to "cut" clear through the weld. It was found that satisfactory welds could be obtained by separating the edges to be welded about 1/8 of an inch and cutting the weld deep and through the plate. When this was done a bead of fused metal was left on the back side of the weld. When it is undesirable to have any protrusions of this kind on the inside of the pipe a water cooled copper strip on a mandrel can be held against the inside of the pipe at the weld. This will permit the fused metal "cutting" clear through and yet will give a smooth inside surface to the pipe. The results of a series of tests on samples of welded pipe are included in the report.

As a check on the laboratory tests 20 foot lengths of pipe were tested under 105 lb. per square inch hydraulic pressure before installation and it was found that tight joints were obtained where the welds were well "cut through," as has been described.

Attention is called to the fact that the dredge pipe and steam heating pipe mentioned were welded by hand by the ordinary "metallic arc" process, and at a saving in cost to the user over standard steel pipe. Automatic welding machines are being developed and with their application to this type of work a still greater reduction in cost should result.

WELDING MONEL METAL

Attempts to arc-weld monel metal have in the past not proven particularly successful, whether by the carbon or the metallic arc method. In such trials the general experience was that it was difficult to produce consistently, welds which were sound and free from blow-holes, ductile and free from shrinkage cracks. The Research Department of The International Nickel Company has during the last year attempted to develop satisfactory arc welding practice for the metal. The particular object sought was to develop a method of producing sound and ductile welds, free from cracks.

It seems apparent from a consideration of the first difficulties encountered in arc-welding that the metal melted by the arc absorbs sufficient oxygen from the surrounding air and that it requires redeoxidation in order to make it again malleable and sound. It may be observed that special deoxidation is not necessary in oxy-acetylene welding because the operator uses a reducing flame which protects the hot and molten metal from the air.

Dr. P. D. Merica and Mr. J. G. Schoener have made some tests using deoxiding coatings which show a remarkable difference between welds made with bare monel wire and wire covered with a deoxidizing coating. The results of these tests are described in the May 1922 issue of the Journal. The agents which have been found to be superior for this purpose are the same as those used in the foundry: viz., magnesium, manganese, and silicon, in the order of their importance for this operation.

The exact composition of this coating powder may vary within moderately wide limits, the essential thing being to introduce into the welded metal about the amounts of manganese and silicon and particularly of magnesium which are generally used for deoxidation in the foundry. Thus there should be introduced from 0.05% to 0.50% of magnesium, from 0.20 to 1.00% of silicon, and at least 0.20% of manganese. The upper limit of manganese is not important, as an excess is not harmful. An excess of magnesium or silicon, however, will tend to produce dirty or brittle metal respectively.

Welds on Monel Metal plate made with the deoxidizer coating are sound and practically as ductile as are welds on ordinary low-carbon steel. Some tensile tests were made on 2" and 3" wide arc-welded strips of Monel plate. The average tensile strength of some 12 specimens was 47,100 lb. per square inch with an average elongation of 9.7%.

The results seem to indicate that the arc welding of Monel Metal is entirely possible when the proper reducing flux is used and in that case the process is not essentially different in detail from that of steel welding. One important variation, however, is that of making the welding rod positive instead of the work. It is also best to build up the weld all in one operation and not to build it up in successive layers, as the latter method will likely give cracks and unsoundness.

MANUFACTURE OF PURE IRON

For Welding Wire

The continuous progress in the art of arc-welding has necessitated large scale production of welding material in this country. In the first commercial application of arc-welding Norway iron was principally used as a welding material but as the demand grew there was a shortage of the Norway product. It was therefore desirable to produce in this country a similar metal, purer if possible, made on a more modern basis.

In the June 1922, Journal, Mr. C. A. McCune has given an interesting review of the progress which has been achieved in the manufacture of welding material. It has not until the year 1914 that wire manufacturers of the United States had a real opportunity of proving that they could meet the demand for welding materials and that low carbon iron, particularly, could be produced here superior to any foreign product. The Emergency Fleet Welding Committee was the first to arrive at some definite specifications and limit of carbon and other elements for the selection of acceptable welding material.

Research has shown conclusively that claims of the advantages of using welding material of an analysis similar to the base or parent metal, particularly when welding mild steel, are not sustained, and the reason for this can be fully understood, when it is considered that arc welding is in many respects is analogous to re-cast-

ing metal. To expect a cast metal of a similar analysis to possess the idential physical characteristics of a rolled and specially treated sheet of plate, is asking more than could possibly be obtained.

Mr. McCune considers that it has been proved beyond question by innumerable practical applications, test specimens, etc., that commercially pure iron wire of correct physical properties possesses every essential that could be advanced for a suitable metal for welding wire steel plates, shapes etc., by either the oxy-acetylene or electric arc process. Furthermore he states that continued research develops that whereas the effciency of a weld in commercial steel plates welded with commercial steel wire may vary, a weld produced with commercially pure iron wire in commercially pure iron plate will consistently approach the characteristics of the plate establishing in his opinion the fact that chemical uniformity of the plate and wire should receive the most careful consideration.

Experience has shown, continues Mr. McCune, that the success or failure of a weld depends on what might be termed the BIG 5 of welding, all of which are practically of equal importance, namely (1) the welder, which includes methods of welding, (2) design of weld, (3) welding equipment, (4) metal to be welded, and (5) the welding wire. Metallurgy distinctly proves that certain elements are detrimental. Therefore, it is only logical to assume that dependable welding material should be as free as possible from these injurious elements.

Mr. McCune considers that welding is an application of metallurgy and engineering and that its study should be so approached. Any common baling or fence wire will no more meet the requirements of a dependable welding material than would metal of this analysis serve as tank plate or locomotive fire box steel. Science, sound judgment, and common sense, prevail in all materials of construction and in welding apparatus, and therefore must apply equally to welding material if we are to be consistent.

Inspection of Welds

Methods of determining strengths of welds without destroying them have been sought for some time. In the minutes of the Welding Research Sub-Committee of the Emergency Fleet Welding Committee are recorded the experimental results obtained when employing an electrical method of testing the efficiency of butt joints as devised by Mr. Conant. Mr. O. H. Eschholz describes in the June 1922 Journal some tests which he has made to try out this method. The specimens were bars 1¼″ x 1½″ x 12″ double scarfed to 45°. Tests were made to determine electrical conductivity and tensile strength.

A study of the data shows that even with this simple testing means, an increase of voltage across the weld signifies a decrease in weld strength. Further activity in the utilization of both magnetic and electrical test methods, has shown the possibility of detecting, in the laboratory, differences in weld strength of the order of 10,-

000 lbs. per square inch. The apparatus employed, while not commercial in its present form, could be made adaptable to numerous welding structures. Mr. Eschholtz quotes Mr. Burrows from the 1919 proceedings of the A. S. T. M. as follows, "the man who denies the possibilities of magnetic (or electrical) analysis today, because of its not being a finished instrument of investigation would have rejected the aid of microscopic analysis or chemical analysis or any of the other means of testing in the early stages of these arts, which have since proved of so great services to man."

Steel Structures

Within the past six or seven years some steel structures have been built with neither pins nor rivets. The members were connected together by arc welding and this development in the art of steel construction is now making rapid progress.

Professor F. P. McKibben of Union College has devoted much thought and study to this problem and has worked up a method of design for structural joints based on some tests made by E. S. Humphreys, Jr., and published in the Iron Age for May 25, 1922. Professor McKibben's paper is published in the Journal for February 1923.

In studying the strength of arc welds it is unfortunate from the structural engineer's point of view that practically all of the tests have been made on specimens cut from butt welds and tested in pure tension. For comparative purposes in ascertaining the relative values of varying amounts of current, varying composition of electrodes, different polarities, etc., tension tests are of great value. However, at the present stage of the application of arc welding to steel structures we are more in need of exprimental data on the shearing strength of arc welded joints rather than their tensile strength.

In the discussion of Humphrey's tests, Professor McKibben points out that when the specimens failed in the testing machine, the plane of fracture, i. e., plane of shear, was not at the base of the triangular fillet but was on a plane extending from the apex of the triangle perpendicularly to the hypotenuse opposite the plane of smallest shearing area. The plates were of ordinary structural steel quality and the electrode was a standard commercial bare wire, high in manganese and low in carbon, sulphur, phosphorus, and silicon. The average shearing strength of the beads for all specimens which failed by shear was 36310 lbs. per square inch.

Now if a factor of safety of four be applied, the safe allowable shearing strength per square inch of longitudinal section of the bead is 9000 lbs. per square inch. Using this value we can determine the allowable safe working stresses in lbs. per linear inch of bead for beads of varying dimensions. For example, a triangular bead ½ inch deep by ½ inch horizontally has a minimum shearing section 0355 inch wide or 0355 square inches per linear

inch of bead, which multiplied by 9000 lbs per square inch the safe shearing strength, gives 3195 lbs. per linear inch of bead. The values for other sizes of bead can be determined in a similar manner.

A formula for length of bead (L) is computed by Professor McKibben in such a way as to make the strength of the weld equal to the strength of the main plates in tension.

Professor McKibben states that physical tests show conclusively that to secure good welds, beads should be laid in thin layers lengthwise of the line of stress and that successive layers should be applied only to clean surfaces which may be cleaned fairly well by a wire brush but the sand blast seems to give better results.

In addition to the development of the formula mentioned above Professor McKibben has designed a riveted truss and a welded truss for the same loading and span which shows a remarkable difference not only in the principles of design but also in weight. This saving in weight as far as the main tension members are concerned is about 16 2-3%

Professor McKibben's papers suggests an important phase of arc welding which has not yet been touched, namely, the design and construction of arc welded bridges and steel buildings. A description of the riveting process together with some fifteen illustrations of actual welding jobs are included to give an interesting comparison between the present day methods and those which might eventually come into use as the welding art progresses.

The examples of welded structures given by Professor McKibben include several at the Schenectady Works of the General Electric Company, as follows. In 1921 a steel framework 40 feet x 40 feet x 40 feet was built for a transformer tower all joints being arc welded. The structure contains 34,000 lbs. of structural steel and, in addition to the electrical equipment carried, supports a small traveling crane. That same year a short covered bridge was constructed between two buildings arc welding being used throughout except at the junction with one of the buildings. A considerable amount of the welding used was tack welding instead of continuous fillet welding.

Within the last few months an electric sign for the radio station W. G. Y. was constructed of structural steel and every joint was arc welded. This sign stands 22 feet high and the letters are 10 feet in height. The base of the sign is approximately 10 feet by 20 feet.

Other instances may be cited where arc welding has replaced riveting in many ways. It is regrettable that time and space do not allow of a more lengthy discussion of this paper, but all interested persons should consult the article by McKibben as published in the welding journal for February 1923.

SHIPBUILDING

Mr. E. H. Ewertz, General Manager of the Moore Plant of the

Bethlehem Shipbuilding Corporation has just completed a paper on "The Applications of Arc Welding to Ship Construction." This paper will soon be published in Marine Engineering in serial form and is an historical treatise on this phase of arc welding. Mr. Ewertz describes his own system of building a welded ship, also other methods of making welded ship joints together with several examples of welded ship construction.

This paper was first presented at Schenectady at a joint meeting of the Northern New York Section of the American Welding Society and the Schenectady Section of the American Institute of Electrical Engineers, last January.

In the February 1922 Journal of the American Welding Society there is described the application of arc welding in the conversion of a steam trawler to an oil lighter at the Hikoshima Dockyard of the Mitsubishi Shipbuilding Company of Japan. The work consisted in raising the upper deck and plating it and fitting the vessel with six new oil tight bulkheads so as to make two cofferdams and five oil compartments. Most of this construction was performed with arc welding. Some of the parts beyond the compartments had to be riveted due to lack of equipment.

Arc Welding was also successfully used in the construction of a steel caisson at the same place. In both cases the arc welding has proved satisfactory.

ARC WELDING APPARATUS

Electric Arc Welding Apparatus has been developed to such an extent that it has now become an important factor in the welding field. Major James Caldwell has admirably described the latest types in a paper presented before the Institution of Electrical Engineers, England, December 14, 1922.

Automatic Metallic Arc Welders

The automatic arc welders made by the General Electric Company utilizes a constant energy welding source. The electrode is fed to the arc from a reel by means of feed rolls actuated by a 30 volt motor which is shunted across the arc when the arc is struck. Regulation of feed is maintained by two contactors which change the direction of rotation of the feed motor when the arc voltage increases or decreases above or below a certain amount, respectively. The machine acts in the capacity of a single welder operator except that a steady arc is more easily maintained. This machine does very good work on straight seams and regular shapes and several variations are now used.

Semi-Automatic Welders

One slight variation from the principle of the automatic machine described above is a semi-automatic welder also manufactured by the General Electric Company. This machine feeds the welding wire through a flexible conduit to a welding nozzle in which the control switch for the feed motor is loacted. This control mechanism operates to start and stop the feed motor. The

maintenance of a uniform and steady arc depends on the operator so that it is not necessary to reverse the feed motor as in the case of the full automatic welder. This type of machine is somewhat more portable than an automatic welder.

Automatic Carbon Arc Welder

During the past year the Lincoln Electric Company has put on the market an automatic carbon arc welding machine. Mr. W. Spraragen, Secretary of the Arc Welding Committee, states: "In this machine the welding wire is placed on the work before welding. The heat of the carbon arc fuses both the wire and base metal forming the weld. Very high speeds are thus made possible."

Alternating Current Contactor

One of the notable achievements made during the past year in the field of alternating current arc welding apparatus has been the development of a safety switch which cuts the power from the welding line and primary circuit whenever the arc is not being drawn. The voltage at all times during welding is limited to a harmless value such as 30 volts.

SUGGESTED RESEARCH ACTIVITIES

Mr. O. H. Eschholz in the January 1923 Journal discusses some of the incomplete development activities in the arc welding field. In many instances an excellent beginning has been made and much good work has been done. A few of the problems outlined by Mr Eschholz are as follows:

100% Fusion Welds

One of the chief aims of welding development is to produce welded joints having physical properties comparable with those of the base metal. To obtain a 100% butt joint in mild carbon steel, it is necessary to employ either a heavy welt, special electrodes, or subject the deposited metal to mechanical work and heat treatment. Recent experience with alloy steel electrodes has resulted in the occasional production of machined welds stronger than the plate. This was found particularly to be the case on welding mild carbon rolled open hearth plate with 3½% nickel steel rods. Although the future of the alloy steel weld is promising, the commercial use of alloy steel electrodes will not be advisable until the cause of wide variations between different welds, made apparently under the same conditions, has been identified and proper remedial measures adopted.

Mechanical Working

Arc deposited metal is obviously a casting with many of the characteristics of cast steel, but like all cast metal it is subject to improvement by processes of mechanical working and heat treatment. In discussing the properties of arc metal unfavorable comparison are frequently drawn with the usual rolled base metal, the fact that the latter has had the advantage of a succession of either mechanical or heat treatments being conveniently ignored. As the arc metal however, is amenable to improvement by such

treatments, it is only just that investigators should determine the margin of improvement possible.

Forging of butt joints has been shown to improve the properties of the filling metal. It is of importance to note that the kneading action of the forging operation may actually produce a better metal in the weld, from the point of view of resistance to fatigue stresses. While forging of all arc welded material may not be practicable, the breadth of the field for joints susceptible to mechanical working, may be indicated by the scope of the automatic hammer-gas method. It is very likely that when the merits of forged arc metal are more widely recognized, a study wiill be made of the effects of various degrees of mechanical working with the resultant evolution of forging systems and procedure applicable to most welds.

Heat treatment has been employed, up to the present time, chieftly for pre-heating or annealing purposes. Recent development has shown that by combining mechanical and heat treatments alloy steel welds may be produced having physical properties comparable to those of the base metal. An example of this is a weld of chrome vanadium tool steel with a nickel steel electrode. The completed weld was forged with an air hammer, annealed from 900°C to room temperature, then quenched at 875 °C in oil and finally drawn at 250°C, to relieve the internal stresses. This specimen was tested and failed at 132,445 lbs. per square inch with an elongation across the fracture of 8.5% in one inch and a reduction in area of 5.6%.

Penetration

Various observers have noted that the depth of penetration and contour of crater surface varies greatly with different electrodes and that a magnetic field suitably disposed will cause further change. It is desired to call attention to the increased penetration obtained with coated electrodes, particularly with coated nickel steel electrodes. The penetration depth is so great that it has been found possible to weld quite satisfactorily, unscarfed, abbutting ⅜ inch plates. Development and control of penetration pheonena would lead to:

(1) The development of a cutting electrode.
(2) Welding of butt joints with a minimum of preliminary scarfing.
(3) Possible reduction of over-head welding.

It is conceivable that electrodes may be developed having such a great penetrative power that it will then be possible to join two over-lapping plates by welding through the upper into the lower thereby eliminating over-head welding to some extent. It is obvious that fusion in this type of weld would be faciliated by preheating the under plate with either a gas flame or carbon arc.

High Speed Welding

Welding speed is fundamentally dependent upon the rate of

metal deposition. This rate varies with such factors as, energy required for liquefaction of electrode material, arc stability, current density and electrical resistance of electrode material. To utilize commercially the advantage of high speed deposition obtainable with high currents, it is necessary to:

(1) Maintain a quiet, stable arc.
(2) Design welded joints so that they will have a high thermal capacity and conductivity.
(3) Develop a high penetration electrode for butt joint welding.
(4) Determine the fillet depth necessary in lap welds to secure 100% welds.

With the ordinary bare electrodes, a violent, sputtering arc throwing hot metal in all directions is a common occurrence at arc current values exceeding 300 amperes. By applying a thin coating of lime as an adherent film, a quiet stable arc will be secured, permitting welding with currents up to 500 amperes. To secure a high thermal capacity in the butt joint, it is necessary to reduce or omit the scarfing operation, the greater penetration obtainable with a high current arc assuring satisfactory fusion.

By a few tests Mr. Eschholz shows that high current welding results in an increase of 100% in the speed of welding a butt joint as shown below. It is conceivable that with the further development of high penetration electrodes, it would be possible to decrease plate separation and thereby increase the speed obtainable with high currents.

Tests have indicated that the welding speed of lap joints is dependent upon two variables, deposition rate and weight of fillet. Butt joints in ½ inch plate may be welded at a maximum rate of 5.3 feet per hour when employing 175 amperes; at 10.03 feet (or more) per hour when using 400 amperes. Lap joints in ½ inch plate may be welded at a speed of 4.5 feet per hour with 175 amperes and 14 feet per hour with coated electrodes and 400 amperes.

In addition to these activities, there are numerous others of a similar type relating to sources of welding energy, accessories, test methods, ferrous and non-ferrous electrodes, deposition procedure, etc., that present a rich field for the investigator wherein development achievements may be readily applied to commercial production.

Arc Welding of Cast Iron

The problem of arc welding cast iron presents another field for the ambitious student of welding. The work of Mr. Namack's Committee points the way to other problems which need investigation. The effect of the method of deposition of the filler metal, current value, angles of bevel, position of weld, kind of electrode, and speed of welding on the hardness and strength of welds are some of the problems suggested. There is great need at the present time for data on these various points.

TRAINING COURSE FOR OXY-ACETYLENE WELDERS

The report given below was prepared by the Committee on Training of Welding Operators of the American Bureau of Welding through the joint co-operation of the American Welding Society, Federal Board of Vocational Education and National Research Council. It represents the best knowledge available not only from the welding standpoint but also from th experience of the Federal Board of Vocational Education in drawing up courses for vocational training. All welding schools are urged to give it the most careful consideration and use it as a guide in laying out proper courses for the training of oxy-acetylene welders. A similar course is being prepared for electric welding which will be available shortly.

C. A. ADAMS, *Director*
American Bureau of Welding.

FOREWORD

The manuscript for this bulletin was prepared by the Committee on Training of Operators. The Committee held several meetings at which most of its members were present. In these meetings the fundamental character of the study was agreed upon. It was the opinion of the Committee that two separate manuscripts should be prepared, the one having to do with oxy-acetylene welding, and the other with electric arc welding. The material in this bulletin relates only to oxy-acetylene welding.

The Committee made an analysis of the work of a gas welder and proceeded to select and classify the information and training which a successful welder must possess, on the basis of the analysis. The information contained in the bulletin will be of service for the most part to those who are responsible for the selection of candidates for training, and to the instructor in charge of the training.

For the information of the person who is selecting the candidates the text includes a discussion of the qualifications which candidates for training should possess.

For the information of the instructor the text includes the fundamentals in gas welding, together with a detailed statement of content classifled under type welding jobs arranged in the order of difficulty.

The instructor should not feel that he is required to set up all of the type jobs suggested or even that he must of necessity use any of these jobs, but that the type jobs have been set up as suggestive jobs arranged in the order of difficulty for a complete training course.

The instructor should feel responsible for checking the trainee against the objective for each of the checking levels in order to make certain that the student is making satisfactory progress. He should also feel responsible for giving to the student the auxiliary information and knowledge of science, drawing, and me-

thematics which has been suggested in connection with the different checking levels.

The text does not necessarily include all the content which the instructor may feel called upon to give. The Committee believes, however, that a mastery of the manipulative skill required to reach the objective in each of these checking levels together with a knowledge of the related information will be sufficient to insure the turning out of men of above average ability.

The bulletin is not intended to be a text-book for the information of the student, since it does not undertake to furnish the content of instruction, but does point out the nature of the training required and the nature of the content.

The Committee feels obliged to the employers of members of the Committee who have made it possible for a number of meetings to be held extending over one or two days.

J. C. Wright, *Chairman.*
O. H. Eschholz.
C. S. Graef.
G. E. Harke.
G. A. McGarvey.
S. W. Miller.
J. W. Owens.
B. C. Tracey.
H. I. Walsh.
J. Wilson.

INTRODUCTION

The analysis of the work of an oxy-acetylene or gas welder as given on the accompanying pages, has been prepared with a view toward supplying a need arising in connection with the training of welders. The application of welding and the inauguration of new methods which may be successfully applied has been so rapid that but little information is available for use by instructors in the many classes being organized in both public and private schools.

An analysis of any occupation or trade is not intended to serve as a text or as a source of information which may be regarded as a statement of standard practices or operations for performing the work. The analysis simply presents various type jobs, together with a statement of the operations necessary to perform each job, and the information and skill which the operator must possess in order to be an efficient worker. In the analysis of the work of a gas welder the committee has classified all welding work into six blocks or major groups, the classification being based upon the kind of metal and upon the operation of cutting. An additional block based upon purely exercise jobs is included as a preliminary step in order that the instruction might not involve the waste of too much material before the operator became sufficiently proficient

to be placed upon productive work. It is the sense of the committee, however, that the *time given to purely exercise jobs should at all times be limited and that the use of practical work is to be recommended as clearly as possible.*

The classification of type jobs is, therefore, arranged in the following blocks:

Block 1. Preliminary Practice Work.
Block 2. Welding Cast Iron.
Block 3. Cutting.
Block 4. Welding Steel and Wrought Iron.
Block 5. Welding Aluminum.
Block 6. Welding Malleable Iron.
Block 7. Welding Copper and Its Alloys.

Within each of the blocks a number of typical jobs have been listed. These jobs were first arranged in a series of "checking levels," a checking level being a convenient point at which it has seemed desirable that the progress of the pupil should be measured from the standpoint of some definite objective to be accomplished. In most cases the checking levels correspond to a specific objective to be attained; in others two or three checking levels have been used in the case of one objective, it being understood at all times that an instructor will feel responsible for checking up his pupils at certain intervals in order to make certain that the instruction has been reasonably well understood and that the student is making the right sort of progress.

Within each checking level a series of type jobs is provided in order of difficulty, with those jobs requiring less skill and knowledge given first followed by those requiring more skill and practice.

It is not expected that an instructor will feel responsible for giving to any one student all or even the greater part of the type jobs suggested. In fact, it is quite possible that he will find it desirable to omit all of the jobs suggested and select in place other jobs which are more applicable to the work for which the student is being trained. He should, however, feel responsible for selecting jobs of similar difficulty in which a similar kind of experience is involved, since in this way the objective will not only be attained but the auxiliary information, knowledge of science, etc., will apply and the instruction, therefore, will be well-rounded at the conclusion of the course.

The analysis also includes a statement of the auxiliary information including:

1. A knowledge of stock, such as an ability to recognize different kinds of stock and to know their working properties.
2. The use and care of tools.

3. A knowledge of safety first precautions which should be taken to prevent accidents.
4. How to prepare the work to be welded.

It is difficult matter for the average instructor to know how much related information in the field of drawing, science, and mathematics should be given when instructing students for work in the various trades and industrial occupations. The work of a gas welder involves the use of pressure tanks, gases under pressure, torches, the question of pre-heating, and scientific consideration of contraction and expansion, studies of which could be pursued scientifically or mathematically to a degree far beyond the ability of the student to comprehend, as well as beyond any need which may arise.

It was, therefore, found to be necessary in the analysis to consider the degree to which the student should be given instruction in these subjects in order that the objective for each of the checking levels might be attained. The information suggested under the heading of Science, Drawing, and Mathematics, is, therefore, limited to the amount which the welder should know in order that he may efficiently perform the welding operations and safeguard the work from injury. The analysis does not include the kind of information which would make the welder a research student or which would enable him to solve problems requiring a broader knowledge of the scientific and mathematical facts in the field of engineering than is indicated.

In conclusion, therefore, the information on the charts can not be regarded as a text-book to be placed in the hands of prospective welders. It can best be used by the instructor as a guide in laying out the course for training. It is recognized that gas welding has many and varied applications; these applications covering the field of the general welder who engages mostly in repair work, the welder in shipyards, in railroad shops, in structural steel, and in specialized manufacturing. In each case the responsibility is finally placed upon the instructor for the selection and arrangement of jobs in the most effective instructional order and for giving the instruction which will best prepare the worker for a given field.

Under the stimulus of Federal and State Vocational Education Acts, the public schools in most large cities, as well as all State vocational education systems, are prepared to assist in the training of teachers for work in this field.

The instructor must be a man who is chosen, (1) because of his knowledge of gas welding as it is applied to the particular industry, and, (2) because of his ability as an instructor. Federal and State Vocational Education Acts recognize that many first-class workmen can become good instructors if trained in the art of teaching. Teaching is itself a skilled trade in which the instructor possesses ability and information which enables him to

put over to the student both skill and knowledge in the most effective manner. In practically every State, and in most of the large cities, opportunities are available for bringing together from ten to twenty skilled workmen into a teacher-training group, this group oftentimes meeting for a total of thirty to sixty hours to receive instruction in the art of teaching. The instruction includes such things as lesson planning, job analysis, and methods of instruction. The service coming under the above acts is available to industry on request to the proper State or local public school authorities.

I. QUALIFICATIONS FOR WELDERS

Selecting Applicants for Training. The peculiar nature of welding work makes necessary the selection of applicants for training with regard not only to their mechanical fitness for the work but also with regard to their ability. The character of the work permits of opportunities for unreliable or dishonest workmen to conceal poor or unsound welds, which may endanger human life and property, and prevent a natural development of welding in industrial establishments.

A consideration of the qualifications requisite to success as a welder indicates that some definite procedure can be set up by which it will be possible to give a degree of assurance that a prospective applicant for training either does or does not possess the necessary qualifications.

Failures of greater or lesser importance have occurred. These failures may be caused by improper design, improper welding methods, lack of knowledge or failure to realize responsibility, not only on the part of the welder, but on the part of those employing him. It therefore seems necessary for those employing or training welders to see that the applicant has the necessary fundamental qualifications to insure his doing good work after proper instructions. These qualifications are as follows:

a. The presence of a job conscience and of a job pride.
b. The possession of necessary physical qualifications.
c. The possession of necessary mental qualifications.
d. A sense of responsibility for "safety first."
e. Ingenuity and resourcefulness.

Job Conscience and Job Pride. The presence or absence of the job conscience or job pride can be determined to a certain extent from the knowledge of the occupation previously followed by the applicant. While a successful experience in any occupation may not indicate that the applicant will become a good welder after receiving proper training, yet, on the other hand, the fact that he has successfully worked for satisfactory periods of time in certain kinds of occupations may be taken as a point in his favor which

indicates that he will make a good welder in so far as it is necessary for him to be a man who takes pride in his work and who is conscientious.

As an illustration of the above statement, certain occupations are submitted as examples which by their very nature tend to develop on the part of the man the feeling of responsibility. While the occupations given below may not be those from which men aspire to become welders yet they may be used to illustrate the point in question.

Certain types of occupations are of such a nature that inspection will not show whether the job has or has not been properly done and therefore the responsibility for successful work rests entirely upon the workman. Where a man can show successful experience through a satisfactory period of years in any one of these occupations we are justified in assuming that he possesses that sense of responsibility known as a job conscience or a job pride.

As illustrations of this group, we have the train despatcher, mail clerk, boiler inspector, elevator inspector, building and insurance inspectors, many railway jobs or occupations, employees in power plants, in chemical plants where occupational dangers exist, as well as any occupation which has been followed by craftsmen, the term commonly used to distinguish a skilled worker from the ordinary quantity production worker.

Certain occupations which have grown up as the result of quantity production, by the very nature of the employment leave little responsibility upon the individual workman, since automatic machines and devices determine the quality and often the quantity of the output. Here also little responsibility is present on the part of the worker for ultimate inspection, the inspector being responsible for the quality and accuracy of the output. This group of occupations due to the lack of immediate responsibility placed upon the worker tends to develop very little his sense of responsibility and job pride. Attention is called to the fact that employment in occupations of this type does not of itself necessarily prevent the individual from becoming a good welder, but on the other hand, experience in such jobs is no indication of his having developed the sense of responsibility and job pride which is desirable as a prerequisite to his being trained as a welder.

Experience in training welders does not indicate that mechanical skill in any of the so-called skilled trades is necessary as a qualification for a welder. However, where an individual possesses the other necessary qualifications, experience in these trades is an asset that would assist him in many of the jobs which he is called upon to do as a welder.

In addition to the consideration of the character of the occupation previously followed, attention should also be given to the average length of employment during which the worker held previous jobs and his reasons for changing.

Physical Qualifications. Since welding requires the worker to use his hands and to depend to a certain extent upon his feet in handling all sorts of castings and parts, it is evident that his physical qualifications will enter more or less into the problem of selection. The following qualifications are therefore presented with a statement as to the degree to which they should be considered.

a. *Weight.* The weight makes no difference in the man's ability to do good welding except that a heavy man, particularly if his weight is not due to mere size, is not so able to get into the awkward positions frequently required in welding work. On the other hand, certain types of welding requires the lifting of heavy parts in which situation a heavy man would have the advantage.

b. *Slow or Active.* Great speed of movement does not necessarily mean rapid or good work. A slow man might make every move count and an active one might waste energy by unnecessary motions, so that the question of whether a man is slow or active should be considered in the light of the meaning applied to the words. It is always true that the man who appears slow and who wastes no time, is better in welding work than the man who "fusses and sputters."

c. *Strength.* For all-around job work or for handling heavy parts, strength is evidently an asset, but there are many welding jobs of a light character in which strength is not necessary and which, as a matter of fact, frequently is a liability because of the lightness and delicacy required in such jobs.

d. *Height.* This has no effect on the ability of a man to do any welding job unless in special cases.

e. *Age.* As a matter of general principle the younger man is easier to train than the older one, but this is frequently not true in individual cases, and the older man is more liable to appreciate and understand instructions and to realize the necessity of thought and study in connection with a subject of which he knows very little or nothing. The question of how old a man may be is of less importance than whether or not he is still mentally and physically flexible so that he can adjust himself to the requirements imposed upon the welder.

f. *Dexterity.* The manipulation of the welding torch is not as simple as it looks and this qualification is necessary in order that the welder may attain facility in his work. The ability to handle the welding tools with perfect freedom will prevent to a great degree the fatigue accompanying long welding jobs, thus improving the quantity and quality of the work done. A dexterous man will often be able to work in difficult places such as overhead welding where others fail.

g. *Eyesight.* This is possibly the most important physical requirement. Both eyes are necessary. If a man can not see clear-

ly what he is doing he has no business trying to become a welder. Certain eye defects may be corrected through the use of glasses but unless the eyesight can be made practically normal in this way the man should not be trained for a welder.

h. *Hearing.* A successful welder should have good hearing. The lack of ability to hear is of greater consequence than the mere ability to receive directions and orders and converse with his fellow beings. There are many noises in the welding shop which defective hearing on the part of the welder would make it impossible for him to recognize conditions affecting his work and his safety.

i. *Nationality.* The influence of nationality upon the qualifications of a welder is more noticeable where the racial habits in that particular nationality are affected by the manner in which they have been accustomed to earn a living. For example, an individual from one of the nations where much industrial development has taken place is more liable to make a good welder than one who comes from a strictly farming, fruit growing, hunting, or other non-mechanical people. It should be noted, however, that the farmer boy from an advanced agricultural district, where much mechanical equipment is used, usually makes a good welder.

j. *Health.* A man to "carry on" successfully as a welder must possess good health. Occupational surroundings, such as heat, and contact with gases and chemical fumes are of such a nature as to make this requirement necessary.

k. *Handicaps.* An all-around welder will require the use of both hands and both feet. Certain specialized work, however, may be done by a man who is handicapped by the loss of a leg or an arm.

Mental Qualifications. It is evident that the successful welder should possess certain mental qualifications. Some of these, such as special skill and special knowledge will be supplied during the training period but for the most part it is expected that the applicant for training will be already mentally qualified. In general, he should possess the following:

a. *Education.* A man should be able to read, write, and speak the English language to an extent equivalent to that covered by a common school education. It is recognized that during the recent war, a number of men who did not possess these qualifications were trained as welders and in some cases they are still employed and making good. These conditions, however, are not the most desirable and as a general rule a man should possess the above qualifications. An elementary knowledge of arithmetic is essential. An all-around welder is called upon at different times to make measurements with precision instruments and to read elementary blueprints, which will require on his part the ability to handle numbers through common fractions and decimal fractions.

b. *General Intelligence.* General intelligence gained through contact with business, through the reading of newspapers, through individual study, through experience in different kinds of work, and through a knowledge of building and construction material, is of great importance to the welder. . A man having a broad general intelligence will be able to adapt himself to the many conditions under which he is required to carry on his work.

c. *Mental Quickness.* The ability to observe and react in an emergency or unexpected situation is a necessary qualification for a welder.

d. *Reliability and Carefulness.* The degree to which a man is reliable and exercises care in the performance of his work will measure his success as a welder. It is necessary that his work be always dependable and that every care be taken not only to prevent injury to the work and to himself, but also to see that the work is done so that there is no future comeback because of failure.

e. *Personal Habits.* The question of personal habits does not affect the welder any more than they affect other workmen. They should, however, be considered in the selecting of candidates to the same degree they are considered in the selection of other employees.

f. *Adaptability.* A man must be able to adapt himself to all sorts of welding conditions. He will often be required to work in undesirable places and with parts that are unpleasant to handle. The disposition and ability to fit into these situations are of great importance to success in welding.

g. *Alertness.* The fact that there are many varying conditions to be observed during the welding of such jobs as heavy steel plate would indicate that the welder should be alert, not only to see, but to observe these conditions and act accordingly.

Fundamentals in Gas Welding. The following discussion of the fundamentals of gas welding have been set up for the purpose of calling the attention of the instructor to the fundamental information which a welder ought to have before he has completed his course. Certain of these fundamentals must be given to him before he is in a position to begin work with welding tools. For the most part, however, the instruction should be given to the man just before or during the time when he is at work upon the type job to which the facts are most nearly related.

Throughout the entire report the Committee has followed the policy of bringing to the attention of the instructor the *character* of the instruction needed rather than the *content* of the instruction. Under this policy the statements made are necessarily brief and the text has not been elaborated into all of the scientific facts which the instructor is expected to give the student.

The subject matter throughout the whole report has been carefully edited so as not to become controversial. The student is more

concerned with the elementary facts which will enable him to become a resourceful welder than with differences of opinion in regard to materials, methods and apparatus.

A good instructor will lay out his training program in advance and will carefully plan each lesson from the standpoint of giving instruction to the pupil at the time when it is most needed. The instructor should adopt the content to his own working conditions and present such additional information as the man may need to know for the particular kind of welding work for which he is being trained.

I. CONSTRUCTION AND OPERATION OF TORCH

a. The torch is an apparatus for safely mixing oxygen and acetylene in proper proportions to produce a "neutral" or welding flame.

b. The difference between cutting and welding torches.

c. Different types of torches use slightly different methods of mixing.

d. The effect and use of different size tips or heads.

e. The essential parts of a torch are body, tubes, tip or head, and valves.

f. Requirements of the Board of Fire Underwriters for safe construction.

II. CONSTRUCTION AND OPERATION OF PRESSURE REGULATORS AND SAFETY DEVICES

a. *Regulators.* Construction and principle of operation of pressure regulators, oxygen and acetylene regulators, importance of tight seats, differences between oxygen and acetylene regulators due to differences in gas pressures and effects of the two gases on metals.

b. *Gauges* Construction and principles of operation, differences due to different gases and pressures, necessity for good quality, need for care in opening high pressure tanks and best construction of gauge to avoid personal injury.

c. *Safety Devices* Back flash chambers, their construction, operation and uses.

III. TROUBLES LIABLE TO OCCUR IN TORCH AND REGULATOR AND HOW TO RECOGNIZE AND REMEDY THEM

Torch.

a. Leaky handle valves.

b. Leaky tips, cause and how to avoid.

c. Passages in tip or handle stopped up with carbon or other foreign matter.

d. Proper method of cleaning tip or handle passages.

e. Grinding in valves and tips and objections to the practice.

Regulators.

a. Creeping of gauge due to leaky or dirty seats.
b. How to replace seats.
c. How to check gauges for accuracy.
d. Effect of buckled diaphram.
e. How to apply new diaphram.
f. Broken, buckled or leaky gauge tube.
g. When to send equipment to factory or service station for repairs.

IV. CONSTRUCTION AND HANDLING OF OXYGEN AND ACETYLENE TANKS OR CYLINDERS

Oxygen Tanks.

a. Made of seamless heat treated steel, Interstate Commerce Commission Requirements, charging pressures, safety plugs and design of valve, care in handling, dangers when exposed to extreme heat or extreme cold, and practice of using as rollers or for other purposes. Valve should be opened slowly and when in use should be opened wide and tight to prevent loss of oxygen, when not in use should be closed tight for the same reason.

Acetylene Tanks.

b. Tanks are filled with porous material in which acetone is contained which dissolves acetylene, reasons for using acetone and porous filler, necessity for compliance with Interstate Commerce Commission requirements, safety plugs, design of valve, reasons for using different threads on oxygen and acetylene valves, differerences in shell construction, necessity of keeping tanks away from fire, reasons for keeping tanks stored in warm place and not exposed to winter temperatures unless protected, need for careful handling, reasons for opening valve carefully and not more than necessary, importance of closing valve when not in use, locating leaks by odor of acetylene, danger of using flame to locate leaks.

V. CHARACTER OF GASES, INCLUDING BLAU GAS, CALORENE HYDROGEN, ETC., AND THEIR USES

In General.

a. All of these gases are used for cutting but none except acetylene is of much importance for welding. Acetylene has the highest flame temperature and the smallest flame; the heat is therefore more concentrated. Care is needed not to use wrong hose connections.

Oxygen.

b. Physical qualities; does not burn but is necessary for supporting combustion; air contains about one-fifth oxygen; can be compressed safely to any desired pressure.

Acetylene.

c. Peculiar sweetish odor; cannot be compressed safely to more than 15 lbs; gives out large amount of heat when it burns; has wide explosive range; its explosions are very violent; reasons for

using acetone and porous filler in acetylene tanks.

VI. DIFFERENCE BETWEEN ELECTROLYTIC AND LIQUID AIR OXYGEN

a. Electrolytic oxygen is made by passing electric current through water, the oxygen and hydrogen so made being collected separately.

b. Liquid air oxygen is made by liquifying air by extreme cold and pressure and allowing the nitrogen to boil off first and the oxygen is then collected.

VII. CHARACTERISTICS OF RODS FOR WELDING DIFFERENT METALS

Attention has been called to these characteristics in connection with the type welding jobs set up on the accompanying charts. The student should be instructed as to the different kinds of rods and the work for which each kind is intended.

VIII. CONSTRUCTION AND OPERATION OF ACETYLENE GENERATORS

a. Rules and regulations of the National Board of Fire Underwriters should be followed in instructing the student as to the construction, installation and operation of all acetylene generators.

b. The same regulations should be followed in the storage of carbide supplies.

c. Safe methods of charging generators.

d. Details of operating generator depend on type used.

IX. CONSTRUCTION AND OPERATION OF ELECTROLYTIC CELLS AND LIQUID AIR APPARATUS

Since the average welder has no contact with electrolytic cells or liquid air manufacturing apparatus, the instructor need do no more than to inform him of these methods of providing oxygen or hydrogen gases. Attention has been called to the differences existing between these gases when produced by these methods in topic No. 6, above.

X. MAKING STRENGTH WELD TEST PIECES

Strength of welds has been referred to in connection with the type jobs on the following pages. No special instruction in these subjects should be given except in connection with the work on these type jobs.

XI MATERIALS

Including—

a. Recognition of materials.

b. Working properties.

c. Chemical Differences.

d. Recognition of alloys.

While some preliminary instruction may be given relating to the different kinds of materials, their working properties and chemical differences, yet for the most part this instruction should be given in connection with the type job in order that the man may not only be able to recognize the different kinds of metal but also to

know how to handle each kind.

XII NOMENCLATURE AND WELDING SPECIFICATIONS

The lack of standardized nomenclature and welding specifications at this time is recognized. The instructor is responsible for informing his students of the latest practices which have been agreed upon by recognized authorities such as the proceedings of the American Welding Society, the publications of the Bureau of Standards and in the Pressure Vessel Code of the American Society of Mechanical Engineers. Further information can be found in the Federal Rules for Steamboat Inspection, in the Regulations of the Interstate Commerce Commission and in the instructions to inspectors issued by insurance companies and State and municipal authorities.

XIII STRENGTH OF PRESSURE VESSELS

It is important for the welder to appreciate that only the very best welding work should be done on all pressure vessels. This appreciation can be secured to a considerable extent by illustrations of good and bad welding as shown through the use of photographs and test results such as found in the report of the American Bureau of Welding on pressure vessels tested at the Bureau of Standards. The man should be informed as to all of the best methods of welding. Definite specifications have been set up in the Pressure Vessel Code of the American Society of Mechanical Engineers for welded pressure vessels.

XIV. SAFETY FIRST PRINCIPLES

The importance of safety precautions should be impressed upon the man throughout his entire period of training. These instructions should cover safety precautions relating to the work itself, to the welder, to the equipment and to other workmen, as well as to the public in general. Information may be obtained from the Board of Fire Underwriters and pamphlets issued by the various state and industrial authorities, such as the pamphlet issued by the U. S. Steel Corporation for guidance of its employees, and the one issued by the Pennsylvania State Board.

XV. USE OF PRECISION TOOLS

The welder is called upon to use tools of greater or less precision such as rules, scales, trams, dividers, callipers and surface gauges. Many prospective welders are not familiar with the above tools and in many cases they have not been accustomed to making measurements to the degree of accuracy required in checking up their work. In many instances the welder will be required to accurately measure to 0.01 inch or less, and it is therefore necessary to train him from the beginning in the use of measuring tools. Attention has been called to the need for measurements in connection with a number of the type jobs.

BLOCK NO. I.—PRELIMINARY PRACTICE WORK.

Checking Level	Job Specification.	Objective.	Auxiliary Information.	Trade Science. Trade Mathematics
1.	**Type Job, No. 1.** Producing and adjusting of torch flame previous to using torch.	To properly adjust torch flame for welding, to realize the importance of care in using the flame and equipment, and to obtain some knowledge of the nature of the gases used.	**Stock:** No recognition of stock is needed at this beginning period. One should be able, however, to recognize the gases used (1) by the appearance of the containers, (2) by their odor, (3) by their burning characteristics. **Trade Terms:** Materials, such as acetylene, oxygen. Tools and equipment, such as torch, tips, regulators, hose, tanks, and containers. **Safety First:** Use of goggles to protect the eyes and gloves to protect the hands, caution so as not to burn others or oneself, and care in directing the flame so as not to injure the equipment, such as hose. Student should be cautioned to extinguish the flame by turning off the gas when not in use.	Creation of the most intense flame by the burning of acetylene by the aid of pure oxygen. Acetylene is produced by dropping carbide into pure water. Oxygen is one-fifth of the volume of air and is produced commercially by (1) liquid air, (2) electrolytic process.
2.	**Type Job, No. 2.** Using torch on piece of cast iron to melt the surface.	To melt the surface of cast iron, successfully overcoming all incidental difficulties.	**Stock:** Recognition of cast iron, (1) by the appearance of the surface, (2) by the fracture, (3) by the action under torch flame, and recognition of its working properties, such as (1) easy melting, (2) fluidity. **Care of Equipment:** Avoidance of flashbacks and knowledge of the proper procedure after a flashback has occurred. **Safety First:** Knowledge of the danger resulting from flashbacks, necessity of keeping torch flame inside the field of vision so as not to injure others, loose tools and materials.	Oxy-acetylene flame is approximately two and one-half times as hot as the melting point of cast iron. The conductivity of two metals such as cast iron and copper vary considerably. Formation of oxide and elimination by flux. Cast iron should be cooled slowly to prevent "hard spots."
3.	**Type Job, No. 3.** Adding metal to a flat surface.	To be able to successfully melt the filler rod into the plate.	**Stock:** Welding rod, flux.	All metals must be melted to make a weld.

4.	**Type Job, No. 4.** Building up "bosses" on flat surfaces.	To be able to build a "boss" an inch in diameter and an inch in heigth, to possess control over the melted metal in flat welding, and to use the proper amount of flux.	**Stock:** The working properties of metal with or without the use of flux.	
5.	**Type Job, No. 5.** Welding two prepared flat pieces of cast iron not over $\frac{5}{16}$ inch thick and 2 inches in length, single V.	To properly weld two prepared, flat, pieces of metal together , using the proper amount of filler.		
6.	**Type Job, No. 6.** Reducing an irregular surface to a definite level.	To produce a level surface free from blowholes and hard spots, to control the metal and prevent it from flowing over unguarded edges. Student should test finished surfaces for imperfections.	**Stock:** Working properties of stock as affected by foreign elements, such as dyes, oils, grease, etc.	**Science—6.** Metal in molten state seeks a level. In welds the molten metal can be maintained out of level by proper handling of the torch.

BLOCK NO. 2.—WELDING CAST IRON

Checking Level	Type Welding Jobs. (A)	Objective for Checking Level. (B)	Auxiliary Information. 1. Knowledge of Stock. a. Recognition. b. Working Properties 2. Use and Care of Tools. 3. Safety First. 4. Preparation. (C)	Science Drawing. Mathematics. (D)
1.	1. Weld Locomotive Bell Crank. 2. Weld Cap for Water Meter. Exhaust Manifold Lug. Tail Stock Clamp Lever. 3. Weld Crack in Driving Box Shoe. 4. Weld Stove Door. 5. Weld Furnace Shaker. 6. Weld Furnace Ring. 7. Weld Printer's Chase. 8. Weld Furnace Door. 9. Weld Piano Pedal.	1. To be able to produce a weld in a simple piece of cast iron in which alignment and finish are of minor importance.	2. (a) Preparation for welding including "V"-ing and lining up the work. (b) Treatment of pieces after welding including slow cooling to avoid hard spots. (c) Finishing.	3.
2.	1. Weld Lugs on Grease Cellar. 2. Weld Flange on C. I. Manifold for Gasoline Engine. 3. Weld C. I. Water Heater. 4. Weld Water Manifold (C. I.) for Gas Engine. (Ford). 5. Weld Lug on Pump Cylinder. 6. Weld Tooth on Gear Wheel. 7. Weld Cylinder Head on Single Cylinder Gas Engine. 8. Weld C. I. Vise Jaw. 9. Weld Lug on 4-Cylinder Block. 10. Weld Broken C. I. Scale Lever.	4. To do a little more difficult work than in previous checking level.	5. (a) Increased accuracy is required in preparation, welding and finishing. (b) The use of straight edge when necessary.	6
3.	1. Weld C. I. Water Back. 2. Weld Crack in Grease Cellar. 3. Weld Lugs on Driver Boxes. (Cast Iron). 4. Weld Cable Drum, where worn out by cable. 5. Weld 6 inch Pump Cylinder cracked from end to end. 6. Weld Water Jacket for Gas Engine. 7. Weld Cracked Jacket on Automobile Cylinder (1 to 6 Cylinders). 8. Weld Building-up Valve Seats. 9. Weld Cracks in Auto Cylinder Exhaust Parts. 10. Weld Scores in Cylinder.	7. To be able to weld jobs involving elementary principles of pre-heating.	8. (a) Necessity of still greater accuracy and care in preparation and welding. (b) Avoidance of distortion from pre-heating or welding. (c) Avoidance of cracking after welding.	9. (a) Expansion and contraction of metals due to change in temperature. (b) The use of steel scale, trams, and dividers as precision measuring instruments.

4.	1. Weld Woodworking Machinery Side Frames. 2. Weld Locomotive Cylinder Flange. 3. Weld High Pressure Steam Manifold. 4. Weld Corners of Water End of Duplex Pump. 5. Weld Printing Press Frame. 6. Weld Cylinder Head (piece broken out of edge). 7. Weld Trailer Box (weld lugs for holding grease cellar). 8. Weld Rack for Steam Shovel (broken in halves). 9. Weld Flange on Sheave Wheel (piece chipped out). 10. Weld Punch Press Frame. 11. Weld Sheave Base. 12. Weld Cylinder Valve Chamber. 13. Weld Tooth in Rack for Steam Shovel. 14. Weld Valve Chamber for Pump. 15. Weld Pump Cylinder (cracked around flange). 16. Weld Gas Engine Crank Case. 17. Weld C. I. Belt Pulley Spokes and Rims. 18. Weld C. I. Pipe 4 inches and up. 19. Weld Fire Hydrants or Street Light Posts. 20. Weld C. I. Radiator Sections. 21. Weld Centrifugal Fan Housing. (two man job). 22. Weld Hoisting Engine Drum (two man job). 23. Weld Steam Chest on Wrecker Engine. (cracked through stud holes in corners).	10. To be able to do more difficult welding jobs involving further application of the principles of pre-heating and the use of a larger torch tip. To be able to co-ordinate work with more than one welder working on the same job at the same time, as well as when working in relays.	11 (a) Instruction in the use of a drill press, air drill, air hammer, sledge hammer and track chisel as they are used in "V"-ing. (b) Instruction on the responsibility of the welder involving the safety precautions which should be observed in order to prevent injury to himself or others. (c) Necessity of good work to avoid failure in service after welding which might endanger property or life. (d) Development of ingenuity on the part of the welder.	12. Further application of measuring tools as mentioned above.
5.	1. Weld Flange on Sprocket Case for Loco Stoker. 2. Weld Cast Iron Roller Front. 3. Weld Large Gear Wheel. (broken in several pieces). 4. Weld Planer Bed. 5. Weld C. I. Crank Case, badly broken. 6. Weld Patch on Radius Pipe for Loco Stoker. 7. Weld Trailer Box (build up where worn. 8. Weld Lathe Apron. 9. Weld Fly Wheel. (broken spokes or cracked hub or piece broken out of hub, wheel Sizes up to 36 inches in diameter. 10. Weld Stamping Press Frame.	13. To use judgment and exercise ingenuity in pre-heating, involving preheating in advance of welding, and re-heating after the job is welded, so as to take care of any ill effects resulting from rapid cooling.	14. The use of various devices such as carbon blocks, carbon paste, etc., to support the molten weld metal and reduce the expense of finishing and cost of the work.	15.

BLOCK NO. 2.—WELDING CAST IRON (Continued).

Checking Level	Type Welding Jobs. (A)	Objective for Checking Level. (B)	Auxiliary Information. 1. Knowledge of Stock. a. Recognition. b. Working Properties. 2. Use and Care of Tools. 3. Safety First. 4. Preparation. (C)	Science. Drawing. Mathematics. (D)
No. 2. (Cont'd) 5.	11. Weld Rim of Gear Wheels. 12. Weld Steam Engine Cylinder. (flange broken). 13. Weld Steam Engine Cylinder. 14. Weld Cast Iron Flange on Cable Drum for Hoisting Engine. 15. Weld Frame for Hoisting Engine.			
6.	1. Weld Locomotive Cylinder. 2. Weld Spoke in Fly Wheel. 3. Weld Gear Wheel (broken in rim). 4. Weld Auto Cylinder head (head not removable). 5. Weld Steam Chest. 6. Weld Spoke or Hub in Large Fly Wheel (made in halves). 7. Weld Steam Hammer Cylinder. 8. Weld Sheave Wheel (broken in halves). 9. Weld Gear Wheel (broken in halves). 10. Weld Patch on side of Sprocket Case for (Loco Stoker). 11. Weld Steam Cylinder Head for Air Compressor (center broken out including stuffed box.) 12. Weld Heater Sections (C. I. heating boilers). 13. Weld Locomotive Valve Chamber (studs broken out of both ends at bottom). 14. Weld Locomotive Cylinder (piece broken out of front end). 15. Weld Locomotive Cylinder (cracked in bottom). 16. Weld Large C. I. Press Frame. 17. Weld Auto Crank Case where opportunity to machine parts is not at hand. 18. Weld Auto Cylinder Jacket (crack close to bore)	16. To weld any weldable job in cast iron.	17. (a) Instruction on the selection of the most improved pre-heating methods. (b) Application of principles and methods of mechanical expansion. (c) Instruction as to the placement of the job during the pre-heating, so as to eliminate unnecessary handling during the welding process. (d) The necessity of anticipating all conditions and operations necessary to complete the job.	18. While the welding of cast iron is practically all in the field of salvage work, it may be necessary in some of the work for the welder to be able to read elementary blue prints or shop sketches.

BLOCK NO. 3.—OXY-ACETYLENE CUTTING

Checking Level	Type Cutting Jobs. (A)	Objective for Checking Level (B)	Auxiliary Information 1. Knowledge of Stock. a. Recognition. b. Working Properties. 2. Use and Care of Tools. 3. Safety First. 4. Preparation. (C)	Science. Drawing. Mathematics. (D)
1.	1. Cutting ¼ inch Plate. 2. Cutting ½ inch Iron Rod. 3. Cutting Off 1 inch Bolt Head. 4. Cutting Off ½ inch to 1 inch Material. 5. Cutting Flat Sheet ¼ inch to 2 inch to line. 6. Cutting Nuts Off of Bolt without damaging bolt threads (1 inch to 4 inches diam). 7. Cutting Angle Iron, Tee Rail Channel Iron and I Beam. 8. Cutting Flat Sheet ¼ inch by 2 inches. 9. Cutting Flat Sheet ½ inch by 2 inches.	19. To manipulate torch in cutting steel.	20. Recognition of different grades of steel by the action of the torch and knowledge of their respective cutting properties. b. Methods and devices for the protection of the welder and others from flying sparks and molten metal. c. Methods of protecting the hose and apparatus from injury by heat, flying sparks and molten metal.	21.
2.	1. Cutting Rivet and Bolt Heads. 2. Cutting Up Scrap Tank. Follow line (sheet rusty on one side and painted on other side). (Explain about gas or oil tank). 3. Cutting Bar Iron (4 in. by 4 in.). 4. Cutting out Hole for Patch side of Tank, 3-16 inch sheet rust on one side and paint on other. 5. Cutting Hole in ¼ inch Sheet. 6. Cutting Hole in ½ inch Sheet. 7. Cutting 18 inch Circle in ⅝ inch Boiler Plate. 8. Cutting Off 16 inch I Beam. 9. Cutting Port Hold in Plate (shipwork). 10. Cutting Hole in Bulkhead for Steam Pipe	22. To cut more difficult jobs and do more accurate cutting.	23. Instruction as to dangers involved when cutting tanks which have contained oil or other explosive gases or liquids. Use of tools in laying out work.	24
3.	1. Cutting Hole in 1 inch Strap Iron. Broken Stud out of Sheet. Stay Bolt out of outside Boiler sheet. Stay Bolt out of Fire Box Sheet. Out Flue. Rivets Out of Sheet. Out Hole in Side-Rod Clevis in Side-Rod. Pipe ((cut off or cut opening for L or T).	25. To cut steel more accurately and without injuring adjacent parts.	26. Use of rivet-cutting tip. Recognition of different kinds of rivets.	27. Methods for laying out work using scribing devices such as straight edge, etc. Methods for laying out pipe intersections.

BLOCK NO. 3.—OXY-ACETYLENE CUTTING (Continued).

Checking Level	Type Cutting Jobs. (A)	Objective for Checking Level. (B)	Auxiliary Information. 1. Knowledge of Stock. a. Recognition. b. Working Properties. 2. Use and Care of Tools. 3. Safety First. 4. Preparation. (C)	Science. Drawing. Mathematics. (D)
	Steel Bushing out of reverse lever and rocker arms.			
No. 3. (Cont'd).	1. Cutting out Link. 2. Cutting Broken Brake Hanger Pin out of Loco Frame. 3. Cutting Steel Shaft 6 inches in diameter. 4. Cutting Sheet to Patterns (shipwork).	28. To cut more difficult jobs, including cast iron and all other ordinary cutting jobs in oxy-acetylene cutting.	29. The use of oxygen and acetylene manifolds. Dangers connected with the use of manifold. Necessary protection of operator when cutting off heavy pieces. Differences between cutting cast iron and steel due to cutting rate, pressure of graphite, wider kerf, greater expense, and the use of different tips and pressures.	30 Cutting cast iron is more of a melting operation than in the case of steel.
4.	5. Cutting Locomotive Frame for Weld with Oxy-acetylene. 6. Cutting Locomotive Frame for Weld with Thermit. 7. Cutting Large Gate from Steel Casting 16 inches to 20 inches in diameter. 8. Cutting Cast Iron 1 inch thick. 9. Cutting Cast Iron 5 inches thick.			

BLOCK NO. 4—WELDING STEEL AND WROUGHT IRON.

Checking Level	Type Welding Jobs. (A)	Objective for Checking Level. (B)	Auxiliary Information. 1. Knowledge of Stock. a. Recognition. b. Working Properties. 2. Use and Care of Tools. 3. Safety First. (C)	Science. Drawing. Mathematics. (D)
1.	1. Weld Whistle Lever Holes up to ½ inch in diameter. 2. Weld Steel Rods up to ⅝ inch in diameter. 3. Weld Auto Brake Lever. 4. Weld Shift Lever. 5. Weld Brake Rods (auto or truck). 6. Weld Build Up Steel Valve Stem. 7. Weld End on Lathe Dog. 8. Weld Handle on Tongs.	31. To be able to make a simple weld in steel.	32. Recognition of different kinds of steel.	33. General effect of heat on steels including their fusing points.
2.	1. Weld Trailer Guide (build up where worn). 2. Weld Angle Iron 4 inches x 4 inches. 3. Weld Filling Up Holes up to ⅝ inch thickness. 4. Weld Round Rods up to 1 inch in diameter. 5. Weld Deck Collar. 6. Weld Automobile Fenders. 7. Weld Wrought Iron or Steel Pipe up to 6 inches in diameter. 8. Weld Side Rod Grease Cup.	34. To be able to weld more accurately and handle more difficult welding jobs.	35. More complete information as to auxiliary information mentioned above.	36.
3.	1. Weld Spool for Brake Hanger (build up worn side). 2. Weld Truck Bolsters and body Bolsters. 3. Weld Foot on Pilot Brace. 4. Weld 6 inch Pipe at right angles making T 90° elbow or 45° elbow. 5. Weld Hatch Frame (ship work). 6. Weld Engine Fly Guard (fly wheel). 7. Weld Auto Truss Rods, Fender Brackets and Pedals. 8. Weld pressed Steel Oil Pan. 9. Weld Plug in Hole in Guide Bar. 10. Weld Dipper Latch (where worn). Steam Shovel. 11. Weld Holes in Brake Hanger (build up worn places). 12. Weld Whistle Lever. 13. Weld Reverse Lever Latch (where worn). 14. Weld End on Locomotive Frame for pilot extension.	37. To be able to handle a torch in more difficult welding and apply the principles of steel welding to more difficult jobs. Students should know the proper tip to use for the particular welding job.	38. (a) Necessary free distance to take care of shrinkage when welding long seams. (b) Use of jigs or fixtures in welding barrel seams. (c) Methods of marking different welding rods and necessity for keeping rods of each kind separate. (d) Working properties of different welding rods under the torch.	39. (a) Chemical composition and general quality of different welding rods, together with reasons for their particular composition to meet certain requirements in welding. (b) Effects of chemical composition, heat and mechanical treatment upon physical properties of welds made with different kinds of rods.

BLOCK NO. 4.—WELDING STEEL AND WROUGHT IRON. (Continued).

Checking Level	Type Welding Jobs. (A)	Objective for Checking Level. (B)	Auxiliary Information. 1. Knowledge of Stock. a. Recognition. b. Working Properties. 2. Use and Care of Tools. 3. Safety First. (C)	Science. Drawing. Mathematics. (D)
3. (Cont'd).	15. Weld Steel Barrels and other steel containers up to 1/8 inch thickness (not pressure containers). 16. Weld New Metal on Stoker Sprocket Wheel where worn.			
4.	1. Weld Teeth in Quadrant. 2. Weld Automobile Frame. 3. Weld Trailer Yoke (center hole worn too large). 4. Weld Valve Yoke (build up stem where worn). 5. Weld Hole in Super Heater Unit Pipe. 6. Weld Open Tanks up to 1/4 inch thickness. 7. Weld Pressure Vessels up to 1/4 inch thickness. 8. Weld High Strength Materials on Structural Steel and Rods up to 3 inches in diameter. 9. Build up Collars on Truck Axles. 10. Weld Small Locomotive Frames up to 4 inches x 4 inches (two man job). 11. Weld Joint of Super Heater Unit (where cut out by steam). 12. Weld Frame Cross Brace. 13. Weld Crack in end of Super Heater Unit. 14. Weld New Joint on Super Heater Unit. 15. Weld Teeth in Steel Gear. 16. Weld End on Quadrant. 17. Weld New Metal on Guide Bar (where worn).	40. To be able to weld more difficult jobs including small pressure vessels.	41. (a) Importance of using the proper base metal for pressure vessels and the selection of the proper welding rod. (b) Instruction in working methods necessary for safety of welder as well as instructions in precautions which should be taken to prevent failure of tank when placed in service. (c) Necessity for appreciation on the part of the welder of his responsibility to make the weld as strong as it is possible to make it to protect life and property. (d) Appreciation on the part of the welder of his own limitations and that he should not attempt jobs which can not be safely welded or that are beyond his individual capacity. (e) Knowledge of the A. S. M. E. Code for Unfired Pressure Vessels and other Federal, State, or local regulations affecting pressure vessels.	42. (a) Reasons why oils or explosive gases in tanks are dangerous in welding operations. (b) Precautions which must be taken to avoid danger of explosion when welding. (c) Instructions as to proper design and construction of tank. (d) Inspection and testing of welds and finished tank. Necessity and methods of inspection and test. (e) Further scientific principles mentioned in No. 39.

5.	1. Weld Key Hole in Valve Stem (fill up where worn too large). 2. Weld Crack in Side Sheet (Loco Fire Box). 3. Weld Trailer Yoke (broken in halves). 4. Weld End Dipper Hanger, Steam Shovel. 5. Weld Mud Ring (cracked in corner). 6. Weld Intermediate Deck Casting (cracked). 7. Weld Seam in Fire Door Hole. 8. Build up Flange on Loco Driver Wheel Tires. 9 Weld Mud Ring (build up over rivet holes). 10. Weld Driver Box (cracked thru top). 11. Weld Pedestal Jaws (build up where worn). 12. Weld Building up lugs on pedestal Jaws where worn. 13. Weld Spoke in Main Driver Wheel. 14. Weld 5/8 inch Pressure Vessels.	43. To be able to weld more difficult jobs and jobs involving greater responsibility, including pressure vessels up to 5/8 inch metal.	44. (a) Instructions in the provisions of Interstate Commerce Commission and A. S. M. E., Federal Steam Boat Inspection, local regulations, State regulations, and insurance company regulations relative to boiler inspection and welding. (b) Necessity of consulting with insurance inspector before beginning work on repairing of boiler or pressure tanks. (c) More complete information on subject matter suggested in No. 41.	45. More advanced information as outlined under 42.
6.	1. Weld Locomotive Frame larger than 4 inches x 4 inches. 2. Weld Side Truck Frame. 3. Weld Patch on Loco Fire Box side sheet. 4. Weld Rail Ends, Frogs and Switches. 5. Weld Patch in Flue Sheet (broken between bridges). 6. Weld New Sheets in Fire Box and new fire boxes. 7. Build up Flat Spot on Loco Drive Wheel. 8. Weld High Speed Steel Cutting Lip on Lathe Tool. 9. Weld Patch in Boiler (side sheet pitted or mud burnt). 10. Weld Cross Head (Cracked thru wrist pin hole). 11. Weld Cross Head (Cracked thru piston fit). 12. Weld Broken Guide Yoke. 13. Weld Gas Engine Crank Shaft (emergency repair job only).	46. To be able to weld all ordinary and some unusual jobs in steel or Iron.	47. Further practical applications of principles stated above.	48 Further instructions as to kind of rods to be used for specific welds. For example, the advisibility of using manganese steel rods for welding frogs and switches.

BLOCK NO. 5—WELDING ALUMINUM.

Checking Level	Type Welding Jobs. (A)	Objective for Checking Level. (B)	Auxiliary Information. 1. Knowledge of Stock. a. Recognition. b. Working Properties. 2. Use and Care of Tools. 3. Safety First. (C)	Science. Drawing. Mathematics. (D)
1.	1. Weld Lug on Inlet Manifold. 2. Weld New Flange on Manifold. 3. Weld Shorten or Lengthening manifold. 4. Weld Broken Crank Case Bearing (bushing support). 5. Weld Aluminum Steering Wheel. 6. Weld Aluminum Fenders. 7. Weld Aluminum Crank Case (pre-heating) (crack in body). 8. Weld Aluminum Transmission Case. 9. Weld Aluminum Water Pump. 10. Weld Crank Case where broken through side or with piece broken out. 11. Weld Sheet Aluminum. 12. Weld Aluminum Tubing.	49. To be able to make a satisfactory weld in any ordinary job involving sheet or cast aluminum.	50. (a) Operating methods when welding aluminum with and without flux. (b) Comparison of the working properties of aluminum with other metals in welding with reference to the following: 1. Impossibility of relying upon its color as a means of knowing when the metal is at its fusing point. 2. Lack of tensile strength of aluminum when heated. 3. Necessity for welder using welding rods of proper quality, specially prepared for aluminum welding.	51. (a) Differences in manufacturing methods involving the following: 1. Use of aluminum-copper alloys for construction purposes. 2. Use of aluminum-zinc alloys. 3. Use of other alloys. 4. Action of the flux on the melted or hot aluminum. 5. Oxidization of aluminum and its alloys as compared with oxidization of other metals, both when in cold or heated conditions. 6. Selection of proper welding rods to secure stiffness or to assure ductility in welded part. (a) Physical properties of aluminum including lightness, brittleness, strength, heat, conductivity and hardness. (c) Chemical properties including resistance to acid and alkalis. (d) Effect in aluminum produced by preheating including local and general pre-heating.

BLOCK NO. 6—"WELDING" MALLEABLE IRON

Checking Level	Type Welding Jobs. (A)	Objective for Checking Level. (B)	Auxiliary Information. 1. Knowledge of Stock. a. Recognition. b. Working Properties. 2. Use and Care of Tools. 3. Safety First. (C)	Science. Drawing. Mathematics. (D)
1.	1. Weld Small Malleable Iron Casting (not requiring lining up). 2. Weld Up Rivets on Rear Axle (Ford housing). 3. Weld Support Arms on Ford Crank Case Pans. 4. Weld Transmission Case. 5. Weld Auto Rear Axle housings. 6. Weld Journal Boxes where cracked. 7. Weld Agricultural Implements (parts). 8. Weld Lug on Pipe Vice. 9. Weld Motor Cycle and Bicycle Frames with bronze. 10. Weld Auto Cylinder with bronze.	52. To be able to weld any ordinary job in malleable iron.	53. (a) Recognition of malleable iron by appearance, grinding, action under torch and chipping. (b) Difference in appearance between malleable iron, cast iron and cast steel. (c) The effect of melting malleable iron with the torch. (d) The effect of bringing to red heat the torch. (e) Recognition of stock white-heart and black-heart malleable iron.	54. (a) Methods of manufacture of malleable iron. (b) Reasons for using manganese bronze, tobin bronze, and similar alloys for welding malleable iron. (c) Preparation of specific malleable iron job. (d) Use of Vee blocks, surface gauge and clamps for such jobs as rear axle housings. (e) Reasons for the use of special tools for special jobs.

BLOCK NO. 7—WELDING COPPER AND ITS ALLOYS.

Checking Level	Type Welding Jobs. (A)	Objective for Checking Level. (B)	Auxiliary Information. 1. Knowledge of Stock. a. Recognition. b. Working Properties. 2. Use and Care of Tools. 3. Safety First. (C)	Science. Drawing. Mathematics. (D)
1.	1. Weld End on Globe or Gate Valve Stem. 2. Weld End of Valve Stem (build up end for new fit). 3. Weld Sand Hole in small Casting. 4. Weld Crack in Globe Valve Body. 5. Weld Small Brass Levers and Handles. 6. Weld End on Globe Valve Bonnet. 7. Weld Small Brass Castings broken or cracked. 8. Weld Hole in Feed Pipe. 9. Weld Copper Pipe at Splice. 10. Weld Copper Heater Coils. 11. Weld Brass Water Heater Segments.	55. To be able to weld simple jobs in copper and its alloys.	56 (a) Difficulties encountered in recognition of stock in order to know its properties due to— 1. Similarity in appearance of different copper alloys. 2. Lack of simple tests. (b) Simple tests which may give some information as to kind of stock. 1. Presence of zinc determined by torch. 2. Hardness determined by drilling or by chipping. 3. By inspecting the color of freshly cut surface. 4. By its bending qualities. 5. By the use for which the part has been constructed. (c) Physical effects on welder and others from breathing of zinc-oxide fumes from brass alloys.	57. Elementary instruction in the following: (a) Physical qualities of different copper alloys. (b) Physical qualities of copper. (c) Chemical composition of copper and its alloys. (d) Effect of heat and mechanical treatment on copper and its alloys. (e) Difference between brazing and welding. (f) Proper Chemical composition of welding rods for copper and its alloys. (g) Reason for use of flux in welding copper and its alloys.
2.	1. Weld End on Line Check Valve. 2. Weld Cross Head Gib (lug broken off) or add metal to take up end play. 3. Weld Crack in Lubricator Body. 4. Weld New Metal in Hole for lubricator filler plug (threads stripped out.) 5. Weld Barrel of test Pump to Base. (brass).	58. (a) To weld jobs where heavy strains are encountered and jobs involving greater difficulty than in the preceeding checking level.	59. Kind of jobs requiring pre-heating and cooling and instruction in the best methods. (b) Precautions to be taken when welding closed vessels.	60. Further illustrations in the principles are given under 57.
3.	1. Weld Crack in Injector, or Lubricator, or Condenser Body. 2. Weld Bronze impeller for centrifugal Pump. 3. Weld Auto Water Circulating Pump. 4. Weld Copper Air Chamber for Water Pump, bursted from overpressure. 5. Weld End Joint on Injector Steam Pipe. 6. Weld Patch on Copper Branch Pipe. 7. Weld Bronze Propeller Tip. 8. Weld Build up Engine Brasses. 9. Weld Fill Shrink Hole in Bronze Propeller.	61. To weld any ordinary copper or brass job.	62. (a) Application of the information suggested in 56 and 59 to more difficult jobs. (b) Instructions as to the difficulties encountered in welding copper and its alloys and types of jobs which should not be attempted. Appreciation on the part of the welder that he is not expected to weld every job brought to him but only those where there is reasonable possibility of doing satisfactory work.	63. Explanation of principles mentioned in 57 and 60 as far as possible within the capacity of the student.

10. Weld 12 inch Brass Flange on Copper Pipe.			
11. Weld Whistle Bell (cracked).			
12. Weld Crack in Locomotive Bell.			
13. Weld Up Steam Valve Seat in Injector.			
14. Weld Bell for Safety Pop (cracked)			
16. Weld Brass or Bronze Grids having broken or cracked members (or similar restrained welds).			
16. Weld very heavy and large Brass Castings such as certain types of Diesel Engine Cylinder heads or other large copper alloy castings.			

THE OXY-ACETYLENE PROCESSES IN 1922.*

G. O. CARTER†

In an industry which has been established as long as has the oxy-acetylene welding and cutting industry there are not apt to be many radical changes. This is the case in our industry in the past year.

On the other hand where processes have not been applied to anywhere near the limit of feasibility there should be room for a wholesome growth, and growth in our industry has been the outstanding feature of the past.

There is nothing new about the welding of steel pipe as it has been going on for a dozen years or more, but the welding of pipe in long stretches is a current development and is probably the outstanding feature of last year's work in the oxy-acetylene welding field. We have most of us heard repeatedly about the long line of 8 inch pipe welded by the Prairie Pipe Line Company and which has been giving excellent service for practically a year.

For the benefit of those associates who have not had the details of this line I take pleasure in stating that the line is approximately 140 miles in length, extending from the Mexia, Texas oil fields to the Hensley, Texas station of the Prairie Company. There are three intermediate pumping stations and the line has been welded into a continuous tube from one station to the other on this system, there being no coupling joints whatever. This 8 inch line carries 750 pounds oil pressure as its maximum and has had a thorough test under working conditions due to the usual washouts during the heavy rains in Northwestern Texas. On one occasion, at least, considerable stretches of this line were washed out of its trench yet it did not carry away, and the line continued to transmit oil at 750 pounds pressure until a ditch could be opened and the line pulled back into it, and even after that rough treatment no leaks developed. This is the kind of a service test which production men look for and has been one of the most convincing arguments in favor of the welded line.

As a matter of fact arguments should not be seriously needed to bring out the economic features of the oxy-acetylene welded line, because from the cost standpoint alone the making of an oxyacetylene welded joint is lower, if done by a well-managed crew, than is the cost for making a screw joint, which is probably the next cheapest method.

In many other fields there are impressive possibilities for welding pipe lines to carry steam, gas and air, as well as oil. Because

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†Consulting Engineer, Linde Air Products Company.

many fine welded pipe line installations are being put in by companies which are noted as leaders through their engineering and business methods, it is only fair for us to assume that the oxy-acetylene welded joint supplies the very best line which it is possible to put in.

An investigation during the past year indicates that some fine steam installations have been made by welding at the Shawsheen Mills of the American Woolen Company; at the Globe-Wernicke and American Can Company plants in Cincinnati; the Union Station in Indianapolis; Warren Iron and Steel Co., Warren, Ohio, and the J. & P. Coats Company, Pawtucket, R. I.

These are just a few of the installations which have been investigated and checked up so that the extent of the work and satisfactory results are well known.

All of this work was not done last year but was investigated because it was believed advantageous to make a partial inventory of the welded installations which have been put in. Many other welded installations are reported to have been made and to be entirely satisfactory, but definite knowledge has not yet been obtained with regard to same.

The information at hand, however, indicates that the welding installations are meeting with the approval of those who already have them and that quite a few new all welded installations are contracted for or written into specifications. One of the most interesting of these is at the plant of the Whitin Machine Company, Whitinville, Mass., where the power plant is being reconstructed and an oxy-acetylene welded installation enables the hooking up of new boilers as fast as they can be installed in place of those which are being removed, one or two at a time. The engineer of the Whitin plant was facing a very serious problem to keep his plant operating during the reconstruction period and has been wonderfully impressed by the way the welding process has permitted the work to go on without interfering with the normal operation of his plant.

Another big welded installation is going in at the plant of the Kieckhefer Container Company at Delair, N. J., where a big mill is being built; the Portland Gas & Electric Company is building a long 20 inch gas line, all the pipe having been bevelled at the mill for oxy-acetylene welding, and all of the 4, 6, 8 and 10 inch steam pipe in the Park Square Building, Boston, has just been welded by the oxy-acetylene process. The foregoing specific information is given with the idea that many who may be interested in welded pipe installations will seek further information on these installations, which are already in operation or are being installed and that engineers may aid each other with regard to the correlating of specific reasons for using welded installations and to provide their clients with operative reasons favorable to the making of similar installations.

As noted above there is nothing new in regard to the welding of steel pipe, but the fact that there are many extensive welded installations around should be a help to the industry to impress all those who are installing pipe that the welded joint is undoubtedly the best, standing up in service without any troubles whatever—when they have been made by qualified welders and when the systems have been thoroughly tested, as has been the case in the installations described above.

This being a discussion of the developments of the past year it is hardly proper to discuss the future, but it seems to many of us that there will be an enormous amount of pipe welding in the near future; in fact any one who is planning a piping installation should thoroughly consider the possibilities of welding before going ahead with actual specifications.

During the investigation of welded pipe installations a visit was made to the Philadelphia Suburban Gas Company at Chester, Pa., to learn more about that company's experience with welded pipe lines. It was found that their first line, over 1,000 feet in length and laid in 1911, was so satisfactory that the company standardized on welding construction in 1914 and has used practically no other type of joint since. Inquiries as to the comparative costs of welded joints at this plant indicated that there has been no question raised as to excessive costs, and the estimates, which have been entirely satisfactory to the Public Service Commission, have been easily met in actual construction work. Here, again, is one of the points often raised by managers when inquiring into the welding problem and it is most satisfactory to have the opinion of men who have been following the welding type of construction for as long a time as at Chester.

In the investigations of the welding of pipe it has been found that in every place where successful welding has been done that a great deal of attention has been paid to the selection of welders and the testing of the finished work.

The tests of pipe installations can be made very easily by filling them with water and hammering the joints before the line is considered ready for putting in the trench or before insulating, if a steam line. This test incidently is along lines of the test proposed for welded unfired pressure vessels.

Perhaps it might be well in view of what I have just said with regard to welded joints in piping to pause a moment and inquire into the reason for this somewhat tardy recognition in pipe work, of the intrinsic value of the gas welded joint. In the early days, welding made great strides in the production of articles formed from steel sheets because it was not only a better and stronger joint than riveting, but as well because a riveted joint even if acceptable from a cost standpoint, was not suitable for the service required of it.

In pipe work, such as I have described, the requirements called

for a fairly high and definite known strength which could be counted upon for long continuous service. This is quite different from a joint where the strength of joint is very much less important. The exacting requirements for oil pipe line work involved not only the development of engineering standards that would insure sound dependable welds under trying conditions out in the open country but also involved the solution of a management question, the distribution of materials and organization of mobile crews to handle the work.

Gas welding has never stopped its forward march in uses for joining metals in the shop, but recent developments indicate that there may be lacking that aggressive spirit which animated the pioneers.

As an example, let us take the growth in the use of concrete which many of us have seen almost from its small beginnings. One can scarcely get out of gunshot of a concrete mixing machine these days. The barrel of this machine revolves and properly mixes the water, cement, sand and gravel. Tightness of the barrel is important. If riveted the rivets are soon worn down and leaks develop. May it not be possible that this offers a field for the extension of welding. Again, welding is replacing riveted construction in the sheet metal pipes conducting material floated from dredges on the way to the point some distance away where the contents are discharged, the water again seeking its level. Friction cut these rivets off. A welded joint answers all the requirements. Considerable progress has been made during the past year in the direction of accelerating the early day plan of assuming that welding was better than riveting until the contrary was proven.

In the field of oxy-acetylene welding the further extension of the process to maintenance and repair work has been most impressive, and a great many plants have built up central welding shops which are quite to be compared to machine shops as run by large plants for maintenance work.

A study of maintenance and repair welding has brought out very strongly that there has been a lack of knowledge about the correct methods of handling cast iron welding. When plants have been instructed to properly preheat work and follow the welding operation with annealing the results have been practically 100%.

The successfull handling of maintenance welding has been taken up with the managements of many plants so that when failure occurs in any of the welding work engineering investigations are usually conducted to bring out the cause for failure, the plant then making provision for following approved practices for handling similar problems of the future. This is quite different from the way welding was handled a few years ago when the welder would frequently advise that the welding operation could not be done, thus covering his own inability or lack of desire to do the work.

In this way the management was led to believe that many welding operations were not feasible.

Oxy-acetylene cutting is so clearly connected to the use of the oxy-acetylene welding process that it should be of interest to all members of this Society. In the realms of this cutting process study shows that there has been an increase in the use of constructive cutting wherein the cutting process saves many hours of work which would otherwise have to be done on heavy machine tools, such as planers.

When machine tool operation is required it takes practically a week to machine out a locomotive side rod from a forging. By cutting the side rod with the oxy-acetylene torch the actual cutting is done in about a half a day and the necessary grinding to finish the rod should not take over another half a day.

Several investigations have come to our attention during the past year with regard to material which has been damaged during or subsequent to the cutting operation, and it now appears certain that oxy-acetylene cutting does not harm good steel which has been properly annealed before the operation and where the cutting is followed by proper normalizing at about 1625 degrees F. for .30 carbon steel. In some cases, if steel has been badly made and is full of segregations, cracks will develop along the lines of local weakness and, therefore, this cutting operation is a possible check on the quality of steel.

The fundamentals of the cutting process and the effect on steel are now so well understood that there seems to be no reason why any serious objections should be raised to them.

The use of the oxy-acetylene process for cast iron cutting is developing slowly, but its possibilities are being better understood, and there have been many valuable applications of this process during the past year. The development of cast iron cutting has been of great interest in that it has brought forth new technical arguments in regard to the oxy-acetylene process, mainly because it has disapproved a great many such statements as, for example, that oxy-acetylene cutting can only be done where the melting temperature of the oxide is lower that that of the metal itself. This claim, which has been considered an axion in the industry for years, may have done harm to many because it was so generally believed to be true that experimentation was discouraged. There are undoubtedly other of the old beliefs which may have little if any truth in them, yet they handicap the industry because they are quite frequently given as alibis for not using the cutting or welding process. Those who are interested in the engineering of the oxy-acetylene processes are trying to run down all the objections which are encountered from time to time, and this will undoubtedly strengthen the industry as time goes on.

As the Welding Society has been very much interested in the possibilities of welding tanks it will be of much interest to know

that two 1,000 barrel oil storage tanks were welded just before the end of the year and are now under service test. The results so far indicate, as was to be expected, that the tanks are oil-tight and satisfactory from a service point of piew. These tanks were tested by putting 2 inches of kerosene on each bottom after the first rings were welded in place and they proved to be absolutely leak-tight. After the tanks were completed they were filled with water and all the joints were hammered with heavy wooden mallets. No other adequate or more severe test could be thought of by those who were interested in the construction of these tanks or same would have been applied. The tops of the tanks were tested with a gas pressure on the tanks, soap and water being applied to all seams and welded fittings.

This is a practical step on the welded tank proposition and it is hoped that in a few more months satisfactory operation of the tanks will warrant further tank construction of like character.

In conclusion I must note, as I did at the beginning, that the oxy-acetylene processes are in such a strong position that the industry is of leading importance, and yet they are not as generally applied as should be the case at present or as will undoubtedly come to pass a few years hence. The effort spent in going into the technical problems of the industry with the managements of plants using the process has certainly been amply repaid by the stabilization of the work and by getting managerial attention, so that the processes are getting very careful and personal study which will undoubtedly aid in their further extension as managers see possibilities of more applications in their own plant.

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Technical Bulletins

These Bulletins are published under the auspices of the American Bureau of Welding. The Bureau is a joint advisory board of the American Welding Society and the Division of Engineering of the National Research Council on welding research and standardization. It acts as the Research Department of the Society.

BULLETIN No. I

Standards for Testing Welds

These Standard Tests Comprise

(a) Shop Standard: A simple standard test for such purposes as checking the work of a welder, testing a new lot of welding wire, and testing the effect of some change in conditions.

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Welding Wire Specifications and Folios

The specifications and folios are based on the data collected by the Welding Wire Specifications Committee as to the chemical analysis of welding wire used for both gas and electric welding in railroads, shipyards and other places and the service results obtained from the use of such wire.

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Standards for Electric Arc Welding Apparatus

These rules provide Standards for use in connection with specifications for the purchase, sale and use of Arc Welding Apparatus. The rules include classification, definition of terms, information relative to apparatus to be supplied by the manufacturer and by the prospective purchaser, respectively, and tests. Price per copy: Members 15c, Non-members 30c.

The American Welding Society

The American Welding Society is organized to provide united and co-operative action in extending the knowledge of the art of welding and its field of industrial application. The field for further application of welding is enormous, and progress in it is being delayed only by incomplete knowledge and by the confusing and opposing claims of competing interests.

The Society acts as a clearing house for information. Through papers and monthly meetings of local sections of the Society an opportunity is created for the individual manufacturer, engineer, plant superintendent, foreman, operator, etc., to contribute his own knowledge in welding and at the same time receive the benefit of the combined knowledge and experience of all other members of the Society. Special publications in addition to the regular monthly proceedings are issued from time to time giving results of researches, standardization work and other information of value to the members.

CLASSES OF MEMBERSHIP

Extracts From By-Laws

ARTICLE I

Section 1. Individuals having received the approval of a majority of the Membership Committee shall become members of this Society upon the payment of dues, except in the case of honorary members who shall be elected by unanimous vote of the full Board of Directors.

Section 2. Membership shall be divided into five classes:

Class A. Sustaining members, being individuals or individuals delegated by corporations, firms, partnerships, etc., interested in science and art of welding, with full rights of membership Annual dues $100.00

Class B. Members, being individuals interested in the science and art of welding, with full rights of membership. Engineers or individuals competent by experience or training to plan or direct welding operations are eligible to this class. Annual dues $20.00

Class C. Associate members with right to vote but *not* to hold office, except in Sections as may be provided for by the By-Laws of the Sections. Supervising welders, inspectors and skilled operators, with three or more year's practical experience in welding are also to this class. Annual Dues $10.00

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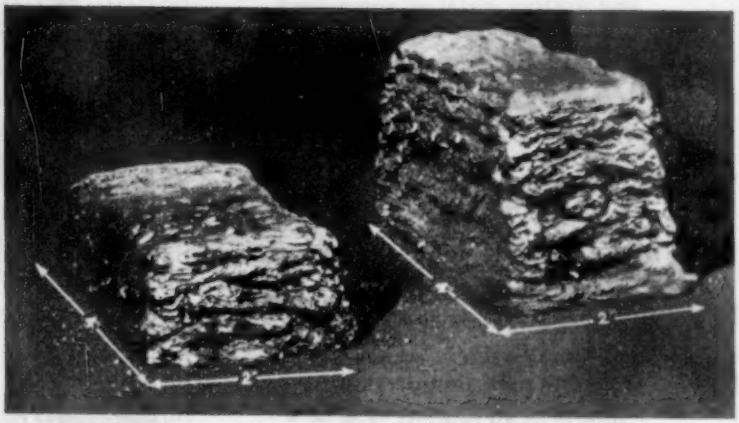

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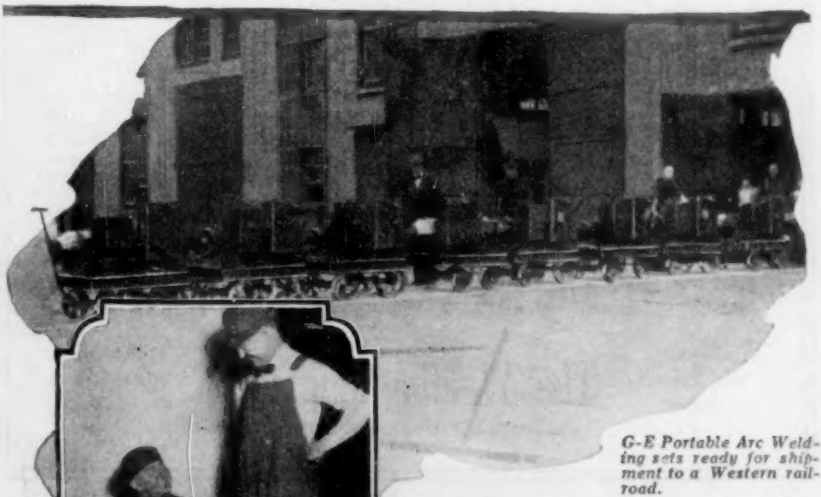

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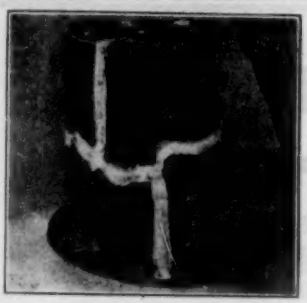

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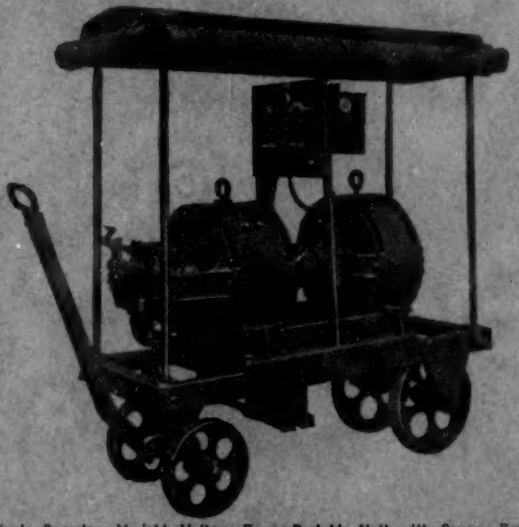

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